METALLURGIA

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Industrialising Russia

The Dnieper Combine

Industrialism is progressing in Russia to a remarkable extent, and huge areas are being developed that formerly were practically uninhabited. The projects planned indicate vision, enterprise, and energy characteristic of the world's pioneers. In this article, a vast scheme of construction on the Dnieper River is outlined. It gives a Russian view on maturing possibilities in metal production, coupled with the generation of power and the planning of a new town.

NEAR what was nothing more than a small village on the Dnieper River, somewhat above Zaporozhe, have sprung up the big buildings of the Dnieper hydro-electric power station and the factories of the Dnieper Combine, spreading over a radius of six to seven kilometres and costing almost a milliard roubles. As far back as the end of the eighteenth century many projects were prepared for the creation of an uninterrupted waterway from the upper Dnieper River to the Black Sea, and the utilisation of the power of the drop in the river, near the famous rapids, for the purpose of generating electricity. None of these projects ever materialised, however. Tsarist Russia of semi-serfdom, involved in heavy debts and other liabilities, could not embark on such a vast scheme of construction, and capitalists in other countries did not consider it profitable to support such a scheme, because there was no prospect of the current being used when the electric power-station had been built. It was thus left to the Soviet Government to visualise the immense possibilities of such a project, and to build the hydro-station on the Dnieper, together with the big works and factories which form the Dnieper Combine.

This hydro-electric power station was designed for a capacity of 800,000 h.p. (550,000 kw.), which is ten times the capacity of the Volkhov power station, and will be the largest station of its kind in the world. The making of the dam above Zaporozhe raised the level of the water in the river by 30 metres; as a result, the distance of 80 kilometres between Dniepropetrovsk and Zaporozhe, which was formerly unnavigable because of the numerous rapids, is now accessible to steamers, barges, rafts, and other craft. Some 6,000 kilometres of waterway on the Dnieper and its tributaries, which were separated by rapids, have now a direct outlet to the Black Sea.

The Dnieper hydro-electric power station not only provides a basis for the development of new industries, for the creation of a new metallurgical and industrial centre in the southern steppes of the Ukraine, but it is an immense factor in the development of agriculture, because of the electrification of the neighbouring agricultural regions.

Panoramic view of part of the dam of the Dnieper hydro-electric station.

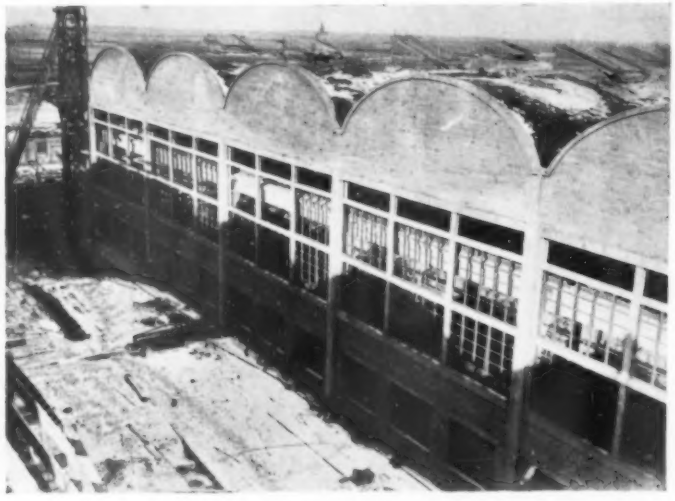
The approximate cost of the hydro-station is 220,000,000 roubles, and it is estimated that by 1933 the station will supply an output of as much as 10% of the entire consumption of electricity in the Union, at a very much reduced cost of production. At present, for instance, the cost of production works out at 4–10 kopeks per kw.-hour, but it is estimated that the production cost at the Dnieper station will be less than 1 kopek per kw.-hour.

The hydro-station, the sluices, the canal and dam, etc., are all being constructed on the most up-to-date lines. The hydro-station will have turbines of 84,000 to 90,000 h.p. The dam, part of which is shown in course of construction

in an accompanying illustration, has just recently been completed, and the first turbine put into operation.

Aluminium Works.

Of the industrial undertakings around the hydro-electric station, which form the Dnieper Combine, the largest consumer of electric energy will be the aluminium works. Aluminium was not produced in pre-war Russia, and the Soviet Union has not yet produced it on a large scale. The first aluminium works, those at Volkhov, which have recently been finished, and these, with the works of the Dnieper Combine, will be the pioneers in the production of aluminium in the U.S.S.R., and it is estimated that by 1933 the annual output will be 20,000 tons.



Finished body of the aluminium works.

The building of the Dnieper Aluminium Combine was commenced in 1930, and will be finished during this year, when it will be put into partial operation immediately. The approximate cost of these works is 142 million roubles, and it is expected that they will consume 35% of the electric energy of the hydro-station. The aluminium section of the combine consists of alumina, electrode, electrolytic works, and works for fluoride salts.

Iron and Steel Works.

The Zaporozhe Iron and Steel Works, which are being built near the hydro-electric station are estimated to cost about 400 million roubles (including houses for the workers). They are designed for an annual output of 1,224,000 tons of pig iron and 1,430,000 tons of steel of various grades, including 80,000 tons of electrically produced alloys.

It is estimated that the requirements of the Soviet Union in steel in 1933 will be 1,700,000 tons. The output of the Zaporozhe Works will be sufficient to meet the requirements of the engineering industries in the Ukraine and the neighbouring southern regions, which, for 1933, are estimated at 1,100,000 tons. These works are favourably situated between its supplies of coke and iron ore, being 200 kilometres from the Donets coal fields and 100 kilometres from the Krivio Rog ore mines. The works will form a huge centralised undertaking with a plant consisting of large modern blast-furnaces and Martin open-hearth furnaces. There will be four blast-furnaces, each with a daily output capacity of 900 tons, which, with the exception of those at Magnitogorsk, will be the largest in the Soviet Union. The steel plant will consist of ten stationary Siemens-Martin open-hearth furnaces of 150-ton capacity, while two converters are being built of 125–130-ton capacity. The rolling-mill will be fully equipped to cope with the production of a wide range of plates and sections, and will include blooming, billet, and slab mills, plate, rod and bar mills, in addition to structural shape mills. When completed it is estimated that the annual output capacity of finished products will approximate to the following :—

	Tons.
Alloys steel	47,700
Copperised structural steel	280,000
Die steel	10,000
Other special steels	20,000
Wire	50,000
Sheet steel of 8 mm. in thickness	180,000
„ 4—8 mm. „	145,000
„ 4 mm. „	280,000

The existence of a cheap supply of electric energy will make it possible to mechanise the various processes in order to eliminate labour, and this is being done as much as possible, despite the fact that ample cheap labour is available in Russia. It is estimated that the average consumption of electric energy at these iron and steel works, excluding the ferro-alloys section, will be 90,000 kw., or approximately 500,000,000 to 600,000,000 kw.-hours per annum. The advantages of the cheap supply of electricity are expected to lower production costs and enable the various manufactures to be produced at lower cost than at other similar works.

The extent of these works will be gauged by the number of workers which are estimated as necessary when the whole plant is in productive operation. Arrangements have been made to accommodate 11,510 employees, comprising 7,480 skilled workers, 2,920 unskilled workers, and 345 apprentices. The executive and administrative staffs will include 560 engineers and technologists, and 805 clerical workers.

Ferro-Alloys.

A section of the iron and steel works is to be equipped for the production of ferro-alloys. As a matter of fact, this is one of the first of the new buildings of the Combine to be finished, and it is expected to be equipped and in operation in a month or so. It is being constructed and equipped at a cost of 16 million roubles, and is designed for an annual output capacity of the following alloys :—

	Tons.
Ferro-manganese	80,000
Ferro-silicon	20,000
Ferro-chromium	4,000
Ferro-tungsten	1,400

Although the estimated value of the annual output of ferro-alloy (14 million roubles) would seem to give these works an unimportant place, the significance of the output will be appreciated. Until recently all ferro-alloys used in the Soviet Union were imported. It was only this year that a newly constructed works of small output capacity was put into operation at Cheliabinsk. The ferro-alloy works of the Dnieper Combine will thus meet a very important need, not only in supplying the requirements of the steelworks in the Combine, but in meeting the requirements of other steelworks in Russia. These works are exceedingly well placed, as, in addition to an ample supply of power, manganese ore, fuel, and other auxiliary materials are available quite near to the works. The main raw material will be the Nikopol manganese ore, and the distance between the works and the mines is only about 71 kilometres.

Coke and Chemical Works.

Of the industries grouped around the Dnieper hydro-electric station which form the Combine, the Coke and Chemical Works will be the smallest consumer of energy, but these works are of importance, since the coke produced will approximate to the quantities required by the blast furnaces of the iron and steel works, as well as other subsidiary plant needing solid fuel. Long-distance transport

will thus be saved, the coke being delivered direct from the coke ovens to the blast-furnaces, to the ferro-alloy works and other works in the vicinity.

The cost of the buildings and installations for these works is approximately 49 million roubles. Four batteries, each consisting of 69 ovens, will comprise the coke-oven plant. The cost of these ovens is over 16 million roubles. The plant in these works is so arranged that when the iron and steel works are extended and the production capacity increased, further coke-oven plant can be installed sufficient to increase the output to a maximum of 2 million tons. These works are expected to employ about 2,000 workers.

The Planning of this Huge Combine.

The creation of so vast an organisation as the Dnieper Combine and in obtaining the maximum advantages from such a combination is only possible under a planned system in which economy in operation is of vital importance. Each process must be under effective control, and of such a character that the raw materials yield the maximum in products. Full use must also be made of the by-products, leaving the minimum to be regarded as waste. Nothing must be left to chance.

The connecting link of this Combine is undoubtedly the electricity supply from the hydro-station, but there are many other factors in this vast scheme of industrialism which are of considerable importance. The aluminium works, for instance, complement one another. The raw material will be delivered to the alumina works, from which, in the form of alumina or aluminium oxide, it will go to the electrolytic works. One of the departments will be equipped for the production of carbon electrodes, which are used in the extraction of aluminium from the alumina. In the process of producing the alumina, iron and silica are separated and are to be used in the production of ferro-silicon. The material, as a by-product from the alumina works, being transported to the ferro-alloy works for final preparation, and in addition there will be intimate association with the iron and steel works and the chemical works.

The iron and steel works will absorb about 16,000 tons of finished products of the ferro-alloy works, the gaseous by-products and the slag which has a high manganese content. The coke-ovens supply the blast-furnaces with coke, while the steelworks will be supplied with large quantities of coke-oven gas. The gas from the blast-furnaces, on the other hand, is to be used at the coke-ovens, whereas the slag is to be utilised for the making of building materials. Of considerable economic advantage, too, are the repair shops and auxiliary services attached to the Combine.

Two electric sub-stations are being constructed to supply current at required voltages. One near the aluminium works will supply low-voltage current, while the other, near the steelworks, will supply current at a higher voltage.

The Hydro-Electric Scheme and Agriculture.

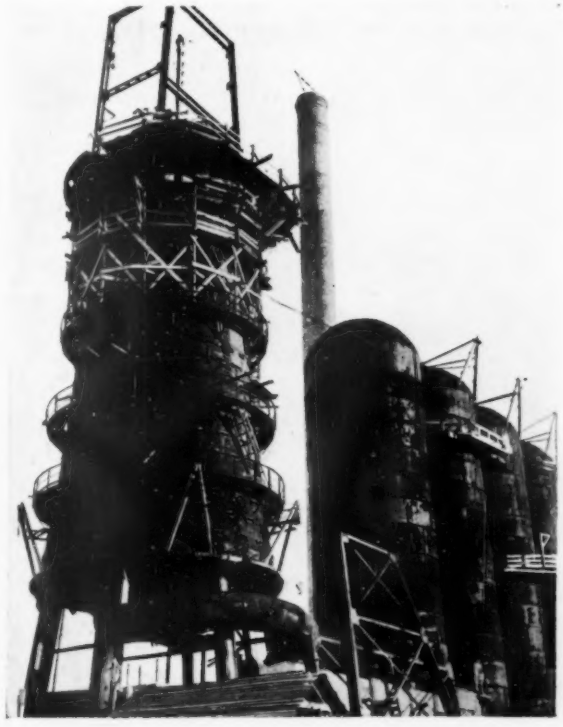
The importance of this electric station to agriculture cannot be overestimated, and in order to grasp more fully the significance of the scheme, brief consideration may be given to this aspect of the Combine's experiment. It will be appreciated that a cheap supply of electricity will make it possible to carry out the highest technical improvements in the collective and state farms of the vicinity. Electricity applied to ploughing, water-supply, threshing, forcing, incubation, milking, lighting, and to cultural and daily needs will strengthen the collective and state farms and make for lower costs of agricultural produce.

An electrical-agricultural combine is rapidly being formed on irrigated land in the region. This is to be an association of agrarian-industrial groups of collective and state farms, whose aim is to raise the technical level of cultivation by the application of electricity, mechanical methods, and irrigation to agriculture. The aim of this combine is not to reconstruct the old village with its individualist method of farming, but to create new collective farms from the very beginning, centred round the transmission lines of the hydro-electric station.

These groups of farms will have the advantage of being connected with the vast regions served by the Dnieper water transport system. They are to develop industries, such as preserved foods, etc., making full use of the electric energy supplied by the hydro-station in the various processes. In the early years their produce will supply the new industrial centre—the Dnieper Combine, Dniepropetrovsk and Kanemskoye—but, as development proceeds, the area served will be increased. Some indication of the importance given to the needs of agriculture is shown by the fact that the total amount to be invested in the Zaporozhe and Dniepropetrovsk Electrical-Agriculture Combine is 100 million roubles.

A New Industrial Centre.

The Dnieper hydro-electric power station, the works of the Dnieper Combine, and their transport system have sprung up in a region where, until last year, there was practically no industry of any kind. All these enterprises

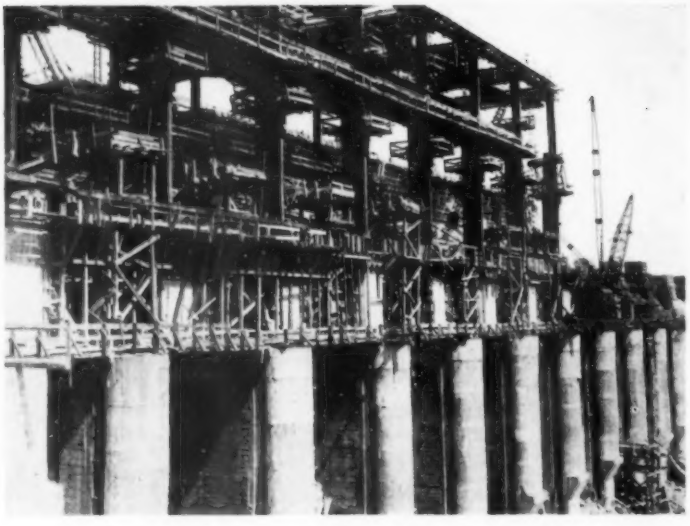


Building of No. 1 blast-furnace.

will employ about 50,000 workers, forming a new industrial centre in the south of the Ukraine. Reckoning an average of three persons per family of each of the 50,000 workers, the population of this new industrial centre will be about 150,000.

The industries grouped around the main transmission line of the hydro-electric station have every prospect of greater development in the future. Naturally, the provision of accommodation for such a large population will entail extensive building of dwelling-houses, as there are only a very few villages in the vicinity of the Dnieper Combine, and the population of the town of Zaporozhe itself, besides being small, is not adequately housed. In the main the workers and engineering and technical staff will be drawn from other industrial centres, to the extent of about 85%. The need for houses to accommodate so large a population

made it necessary to invest considerable sums in the house-building during the building of the Combine and the hydro-station. At the beginning of this year building was commenced on the left bank of the Dnieper, on the area between the Dnieper Combine and the old town of Zaporozhe. Several residential quarters consisting of three- and four-storied comfortable, well-appointed houses, have already been finished. These residential quarters are the beginning of Greater Zaporozhe, which will be one of the first completely new towns planned by the Soviet Union. It will become a model town, not only because of its comfortable well-appointed flats, but because of the new living conditions being created, based on the socialisation of economic, social, and cultural functions. The new industrial town will also be the cultural centre for the neighbouring collective and state farms.



Dnieper hydro-electric station in course of construction.

In Greater Zaporozhe plans have already been made (some of which are already being carried out) for the building of houses—communes, factory-kitchens, public dining-rooms, baths, laundries, crèches, kindergartens, co-operatives, clubs, schools, institutes, theatres, cinemas, squares, etc. A sum of 250 to 300 million roubles is being expended on the building of houses, provision for adequate gas and water supplies, a sanitary system, motor-buses, and other means of communication. The amount of 130 to 140 million roubles is to be expended on these purposes by 1934.

Protection of Steel Water Tanks

Red Lead Paint recommended for the Protection of Steel Water Tanks.

IN view of the widespread researches being undertaken on the subject of corrosion considerable interest is attached to the recent recommendations of the American Railway Building and Bridge Association for the best methods for the protection of steel water tanks and other exposed structures. The method advocated and put into practice consists in using quick-drying red lead paint composed of 100 lb. of red lead in oil, 1½ galls. boiled linseed oil, 3 pts. turpentine, and 2 pts. liquid dryer, and to each gallon of the paint so obtained 2 lb. of finely-powdered litharge (lead monoxide) is added immediately before application. One week must elapse between the application of priming and the second coats, and 48 hrs. between the second and third coats, and after the latter has been allowed to dry for 48 hrs. the tank is ready for filling with water.

The recommendations of this Association are based on extensive experience in the protection of railway plant and exposed equipment of every description. The modern "non-setting" varieties of red lead, which do not harden in storage containers, enable the paint to be supplied in bulk form ready for use, and facilitate its application for exposed structures. This is due to the small proportion, not over 6%, of free litharge contained in non-setting red lead, an effect produced by careful scientific control in the process of manufacture. It is effected by oxidising molten lead with air in two stages, first to lead monoxide, at not over 645° F.; and secondly, at a higher temperature, not over 1,000° F., in order to produce red lead. In this connection it is of interest to note that the British standard specifications require a minimum of 93.15% true red lead, with not over 6% litharge, while the American standard specifications are on the same lines; while the new suggestion of the addition of a small quantity of litharge to the paint immediately before application is certainly of interest.

Familiar knowledge also is the fact that in the corrosion of steel, iron, or other material by water, partly due to dissolved oxygen, "initial" corrosion takes place, that is, the corrosion of the clean metal surface commences at a fairly rapid rate, and then diminishes considerably, due to the formation of a protecting film of oxide, and some notable research work has been accomplished by R. H. Brown, B. E. Roetheli, and H. O. Forrest, which is described in a recent issue of *Industrial and Engineering Chemistry*. These investigators have determined with great accuracy the initial corrosion rates of aluminium, zinc, copper, nickel, tin, silver, and iron and steel. Essentially the method adopted consists in the use of a small rotating cylinder of the metal, which has been rendered oxide-free by treatment with hydrochloric acid, and subsequently rinsed in a stream of oxygen-free water until all traces of acid have been removed. The metal so treated is then subjected to the action of water containing dissolved oxygen, and the rate of corrosion measured by determining the decrease in the oxygen content of the water.

Output of Iron and Steel in Soviet Russia.

The output of pig iron in the U.S.S.R. during the first six months of 1932 equalled 3·0 million tons, as against 2·3 million tons in the corresponding period of 1931, and 2·1 million tons in the corresponding period of 1929. The Soviet output of steel during the first six months of this year was 2·9 million tons, as against 2·6 million tons in the same period of 1931, and 2·4 million tons in 1929.

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THE BRITISH JOURNAL OF METALS.

INTERNATIONAL CO-OPERATION IS LEADING TOWARDS INDUSTRIAL STABILITY

UNDER the stress of adversity the world is gradually moving towards a sounder and more orderly economic system. There is a greater appreciation that far more questions are of international concern than was formerly recognised, and there is, in consequence, growing acknowledgement of the interdependence of business, national and international. Before the war the depth and extent of a people's international outlook was frequently obscured; since the war it has been gradually growing and has become insistent and unmistakable. Formerly, states regarded commercial relations between their subjects as a matter of bilateral interest only. Trade arrangements were made by pairs of states, and the necessity which led to the most-favoured nation treatment was not realised as resulting from the essential economic interdependence of the different parts of the world. The stress of economic conditions experienced during the last few years has forced people to realise that every country depends essentially on the prosperity of every other country; that the interests of all countries in quick and easy transit, in sound credit and confidence, in stable government, are not only common to all of them, but are amongst the vital conditions of their welfare. Thus, insularity is giving place to a realisation that economic dislocations and political disturbances, whether in Ireland, Germany, or elsewhere, have important repercussions.

Probably the most significant of recent agreements, which shows very forcibly the modern international trend, is that reached at the Lausanne Conference. The settlement reached at this Conference will, we are convinced, prove to be the initial step towards increased confidence. Although this agreement is not yet ratified, it is unlikely to be reopened excepting to reduce it. It is true that, in the suggested world's economic conference, the United States have indicated that the debt problem should be excluded from the discussions, but this problem is now so interwoven in the world's economic structure that it must be considered in one form or another; it is inevitable to a satisfactory solution of numerous problems that will be discussed. There can be little doubt that the agreement will be ratified as a result of a satisfactory settlement of the debt problem with the United States. We are confident, however, that a more amicable solution to the armament problems will have a considerable influence. These cause grievances which fester and threaten peaceful relations between countries. A reasonable solution to the armament difficulties would be the means of reducing the debt to insignificant dimensions, which would materially aid the forces working towards economic recovery. So far the progress has been relatively small; there is still room for a considerable reduction in armaments and for the removal of gross inequalities that still exist between nations.

Although primarily concerned with Empire economic problems, the conference at Ottawa has an international significance. The British Empire is a Commonwealth of Nations adopting co-operative independence. Progress towards this end has been rapid, particularly since the war. The participation of the Dominions in the war modified their status alike in the British Empire and in world politics. They passed at a single bound from protected colonies to participating nations, and they reasonably claimed the rights pertaining to this position. These rights were recognised by the inclusion of Dominion statesmen together with representatives of India in the Imperial War Cabinet, which was charged with supreme control. This Cabinet was subsequently placed on a more permanent basis. Thus, there came into existence a real Imperial executive, but without real Imperial legislature. This Empire Conference now sitting is intermittent in session, and in former instances has been purely advisory in function. The question naturally arises, will it eventually evolve a body representative of the Dominions and perhaps of India, which shall be competent to legislate for the Empire as a whole, to which the Imperial executive shall be responsible? Such a step would provide a rapid development towards the federal unity of the Empire, and would have a powerful influence on the world.

It will be remembered that the Dominions claimed a place at the Paris Conference, not merely as members of the British Empire, but as nation-states, co-ordinate in status with the other sovereign states, and a similar status was conceded to them on the Council of the League of Nations. But when the extent of the British Empire and its inhabitants are considered, the dominant thought which they inspire to-day in all peoples of the Empire is less of power than of responsibility, not so much of political or economic prestige, as of opportunities for service to mankind. Thus, despite the efforts now being made to establish closer economic unity within the Empire, we believe with Lord Aberdeen that the outlook of the new British Commonwealth is international. Each nation concerned can give of its communal life something to enrich the world. Its sole aim is in the wider interests of international peace based upon the fullest and freest commercial and industrial enterprise. It has come into being in the tragic aftermath of the world war; it points unmistakably towards the one safe road of world peace—the universal recognition of co-operative interdependence of every nation and all peoples.

A successful result of the Ottawa Conference should mean the subjugation of purely selfish interests to the general well-being of all the nations which constitute the British Commonwealth. Such a result would have a valuable moral effect on the peoples of all nations, and would indicate possibilities for its wider application. The interdependence of all business is both national and international, and a solution to the Empire problems will pave the way to a solution of world problems, but it will only be possible if the problems are faced in a spirit of co-operation. Europe and large parts of Asia are like the destitute and unemployed, gradually sinking and becoming daily more demoralised. A strong effort is required to give any chance to these nations. No one nation can achieve this task; it is a task for all nations of the world, and a world conference, by subjugating conflicting interests to the common good, would remove or minimise restraints to world trade, and by adopting a better spirit of international co-operation would promote trade, giving greater stability and increasing confidence of which the world stands so much in need.

Rapid Russian Development.

THE Russian revolution, which took place in the confusion of the great war, has brought into existence conditions that are of immense interest and importance. The whole outlook of its people has been changed. Under the present *regime*, Russia has socialised its land, capital, and means of production, and is applying all the energy at its command in attempting to adjust its resources to the needs of its people. Possessed of vast territory rich in natural resources, colossal industrialisation schemes are being developed which constitute vital features in her economic plan.

Immediately after the revolution the problem of industrialising the Urals was given serious consideration, the iron ore deposits were investigated, and tests of the ore in the so-called Magnet mountain of the southern Urals showed it to be remarkably rich in iron content. A plan was subsequently developed by the Soviet Government to combine the exploitation of Ural ore with Kuznetsk coal and the construction of two steel combines, one at Magnitogorsk and the other at Kuznetsk, is one of the most courageous plans that has been realised. Only recently the second Magnitogorsk blast-furnace was put into operation, and these two furnaces are designed to yield a daily output of approximately 2,500 tons of pig iron. When it is realised that for thirty years preceding the war the Russian iron and steel industry produced a total of 4.2 million tons of pig iron, while a greater amount is now produced in one year, the progress that has been made will be appreciated.

Last year only four new blast-furnaces were started in the Union, while during the present year construction commenced on 24 new blast-furnaces and 65 open-hearth furnaces; eight of these blast-furnaces are now in operation. It is interesting to note that the methods of production and the servicing of these furnaces are all mechanised; ore and coke are delivered by automatic unloading cars, and control apparatus of all the mechanism is concentrated for operation by a single operator in each case. The new blast-furnaces are radically changing the position of the Soviet iron and steel industry, and it is expected that they will be instrumental in increasing the output, from the 100 furnaces now in operation, from 4.9 million tons last year to 10 million tons this year.

Another project of immense importance, now in course of completion, is that concerned with the Dnieper Combine, the extent of which is indicated by the Russian view of the scheme published in this issue. In this case also a blast-furnace is being erected because the position is favourably situated in regard to coal and iron ore; Dunets coal and Krivoi Rog ore being within a convenient distance. The most important part of this scheme is the construction of the dam, which has raised the water level 30 metres and given power for a huge electric generating station. The uninterrupted waterway from the Upper Dnieper River to the Black Sea, long contemplated, has now materialised, while the power station provides a basis, not only for the development of industry, but for developing agriculture.

In the consummation of these projects whole areas that were formerly almost uninhabited have become seething with life and activity in the building of industrial centres, and in a comparatively short time towns have been created which are constituted on model lines, in that the living conditions for the inhabitants are based on the socialisation of economic, social, and cultural functions.

It is significant that while Russia is pressing on with her projects and establishing industries on a mass-production plan with remarkable vigour, other countries, in which industrialisation has long been developed, are suffering under the lash of adversity and in great need of a more orderly economic system. It has always to be remembered, of course, that present Russian economic and industrial problems constitute what has been aptly described as an unprecedented national experiment.

Simplifying the Production of Foundry Irons.

FOUNDRY iron is a class of pig iron which, in modern blast-furnace plants, is usually made continuously, although changes may be made in the furnace burden and in operation to produce basic iron. Such changes call for considerable experience on the part of the furnace manager in order that the adjustments necessary are made with the least amount of disturbance in the working of the furnace. Despite every care, however, there is always a period of derangement caused by a change in the burden and some time elapses before conditions become normal, during which time off-grade material is produced.

In producing foundry iron the question of grade must be considered, and frequent changes must be made according to the grades required. Formerly, grades were judged entirely by fracture, but it is now generally recognised that chemical analysis is a better guide to the quality of an iron than visual inspection, because it provides a scientific basis for the determination of foundry mixtures. Users of foundry iron are therefore purchasing largely by analysis, and many more compositions are now called for than were customary when fracture grading was relied upon. Meeting the various requirements is imposing difficulties on an industry that is already severely handicapped in meeting keen compelition, and in an article published elsewhere in this issue we suggest the desirability of standardising suitable grades of common foundry iron.

It is appreciated that many difficulties would need to be overcome, but they should not be insuperable, particularly as the iron industry is exploring every possible avenue likely to improve trade and lead to increased economy. Representatives of users and producers, through their respective organisations, could do much to reach agreement on the subject providing it is approached in a spirit of co-operation. We think that some modified system of grading foundry pig iron, with the object of simplifying production and reducing costs, is long overdue and offers a field for profitable investigation.

Institutes' Joint Autumn Meeting.

THE Iron and Steel Institute and the Institute of Metals will hold a joint autumn meeting in the rooms of the Institution of Civil Engineers and of the Institution of Mechanical Engineers on September 12—15, at which joint technical sessions will be held. Thirty-one papers are to be presented dealing with a wide range of subjects, and, in addition, arrangements are made for many interesting works visits, including the National Physical Laboratory, General Electric Company's Research Laboratories, Acton Refinery of The Mond Nickel Co., Ltd., and the Dagenham Works of the Ford Motor Co., Ltd.

The annual autumn lecture of the Institute of Metals is to be delivered on September 12, by Dr. H. J. Gough, M.B.E., his subject being "Corrosion Fatigue in Metals." Both ferrous and non-ferrous metals will be considered in this lecture, which will be given at the Institution of Mechanical Engineers.

The Institution of Mechanical Engineers.

THE summer meeting of the Institution of Mechanical Engineers will be held in Canada and America. The programme arranged is very comprehensive, and includes a brief tour of Quebec, tours and visits to works at Montreal, Ottawa, Toronto, Hamilton, Brantford, Niagara Falls, Rochester, Schenectady, and New York. In the Convocation Hall of the University of Toronto Dr. F. A. Gaby will present a paper on "The Generation and Distribution of Power under the Administration of the Hydro-Electric Power Commission of Ontario," while at Niagara Falls an address will be delivered by Mr. C. L. Stevens on "The Point Plan of Rewarding Management and Labour." Complete arrangements are made for the round trip from Southampton, August 19, back to Plymouth, September 19.

Precious-metal Scrap

Recovery of Gold, Platinum, Palladium, and Iridium.

(Specially contributed.)

Precious-metal scrap, because of its increased value, has been much in evidence of late, and the author, in this article, describes a rapid and direct process of recovery.

JEWELLERS' scrap accumulated from a wide variety of sources contains, besides the usual gold, silver, and platinum, small quantities of the rarer metals—palladium and iridium. The scrap collection includes old rings, brooches, pins, bracelets, pendants, and numerous small oddments. To this might be added such odd materials as platinum pins used for false teeth, and special studs made by working jewellers for industrial purposes.

Of the little literature which has been published on this subject, most of it relates to direct laboratory methods of dissolving the scrap and separating the respective metals by chemical reagents similar to the analytical system. Whilst this may be convenient where very small odd lots exist and time is a factor of no consideration, a much more satisfactory system is adopted where the work is conducted regularly.

Where the scrap accumulation contains much in the way of impurities—copper, tin, lead, or other base metals—the mass requires a preliminary treatment, and the lot is melted in a pot and cast as a bar. In this process the actual amount of impurities present is of little or no importance.

The regulation method of cupellation of silver on the "test" need not be elaborated upon; suffice it to mention that all such bars are simply thrown on a bath of molten lead, and the base-metal impurities removed by the oxidation of the air. When these bars are exceedingly impure, and particularly when much copper is present, such as when many rings have been melted down, an excess of lead must be added. This is done by making a constant addition of lead plates until a sample drawn from the bath shows a clear, glistening surface. Copper is the last of the base metals to be burnt out, and the sample shows a black surface so long as it is present. There is invariably a large excess of silver over gold and platinum in the average scrap heap, otherwise it would be necessary to add silver to bring the resulting metal to the proper concentration for the next stage of the process. When finished, the metal is cast into anode moulds for electrolysis.

Electrolysis

Rich scrap—*i.e.*, mostly gold, silver, and platinum—could be directly cast into anodes and electrolysed in place of melting down to a bar for the previous process. With heterogeneous scrap, however, it is safer to adopt the foregoing process—firstly, in view of the impurities, and secondly, because the proportion of silver might cause difficulties during the electrolysis.

The anodes are electrolysed by either of the methods adopted by the mint refineries—*i.e.*, the "Moebius" or the "Balbach Thum" process. Since jewellers' scrap does not accumulate to such vast proportions, it would be needless to install a large plant for the purpose, and an improvised or modified bath, or set of baths, will give the necessary separation with great accuracy.

The scrap now in the form of small square anode plates is fixed in the bracket of the plant in a dilute nitric acid solution, and the current switched on. The current is maintained at 50 amps per sq. ft., and an excess of silver, about 3%, is always kept in the liquor to prevent any slight proportion of impurities finding their way into the deposit. A slight amount of copper (up to 4%) is beneficial to the solution rather than detrimental, in that it causes the silver to deposit with a better and brighter appearance.

The result of the electrolysis is that silver deposits on the cathode as a white shining powder, whilst the insoluble matter remaining at the anode contains gold, platinum, and any of the rarer metals present. The plant simply consists of rectangular stoneware troughs, the bottoms of which are lined with carbon blocks. Above this are the wooden brackets, which contain the anodes and are surrounded by cotton bags to hold the slimes which remain.

Anode Slimes.

The insoluble slimes are dark brown in colour, and are chiefly composed of gold with about 3–4% of platinum, and, say, 0·4% palladium. Although the original scrap was not known to contain palladium, it existed chiefly in the platinum ornaments, as also a still smaller proportion of iridium.

To remove any remaining silver, the slimes are given a preliminary treatment, boiled in strong sulphuric acid in a special iron pot, and the solution treated with common salt to precipitate the silver.

The slimes are now digested in *aqua regia* in a large flask, which dissolves out the gold, platinum, and palladium. Since the reaction is not complete, it is usually necessary to remove the insoluble residue, melt it in a pot, and grain it by pouring into water. These grains are then digested in nitric acid, which usually suffices to remove all remaining soluble matter.

The slight dark iridium deposit left is composed of approximately :—

	%
Iridium	75
Platinum	2
Rhodium	3
Ruthenium	1
Gold	0·7

This is disposed of for purification.

The solution of gold, platinum, and palladium is treated with ferrous chloride, which precipitates the gold by reduction. This is filtered off, washed in hydrochloric acid, dried and melted in a crucible to bar gold. To remove any scale formed on the skin by contact with the iron mould, the little ingot is pickled in hydrochloric acid. Should there be any doubt that possible impurities still remain, the gold while molten in the pot is treated with a few bubbles of chlorine gas from a silica tube attached to a small chlorine cylinder.

The filtrate from the gold precipitate is treated with ammonium chloride, which precipitates platinum as a bright yellow precipitate. This is washed in dilute hydrochloric acid and placed in a pot where it is roasted to the grey sponge. The sponge is washed in hydrochloric acid, dried, and melted to a small platinum ingot by special oxy-hydrogen blowpipe.

The filtrate from the platinum contains any little palladium which exists, and this is simply precipitated by boiling with scrap iron. The dark precipitated palladium is also washed with hydrochloric acid, dried, and reduced under hydrogen in a crucible to metallic palladium. In this way the remaining filtrate is composed of ferrous chloride, which is evaporated and utilised for precipitation of the gold as before.

The whole process is extremely rapid and direct, and it is doubtful if much improvement could be made on it as it stands.

X-Rays in the Aluminium Industry

By N. C. Hypher, B.A., B.Sc. (Lond), D.M.R.E. (Camb).

(Consulting Radiologist, High Duty Alloys Ltd., Slough, Bucks.)

The usefulness of radiography in the aluminium alloy industry, the type of equipment and apparatus employed, and the technique developed in X-ray examination of specimens are discussed.

ALUMINIUM alloys, on account of their low density, are easily penetrated by the X-rays, and pictures of castings or forgings, of thicknesses up to 6 in. can be obtained showing good detail. The test of radiography can be applied to the raw material or the finished product, and it is being applied with considerable success in research work and in the aluminium alloy industry, particularly where a special part is to be subjected to unusual stresses. I have, for instance, X-rayed all the R.R. series of alloys which have been used with great success in the record-breaking engines used to capture pride of place on land and sea, and in the air. Much of this metal was used in the Supermarine Rolls Royce plane, which flew last year at over 400 miles per hour; in Sir Malcolm Campbell's "Blue Bird" (Napier Lion engine), and "Miss England III.," the speed boat piloted by Mr. Kaye Don which recently exceeded 120 miles per hour.

Fig. 1.—X-ray transformer unit by A. E. Dean and Co., London

The type of X-ray generator best suited for this kind of work is one capable of producing high-tension voltages stepping up gradually from 50,000 to 200,000 volts. One of the simplest and least bulky modern units is shown in the accompanying illustration, Fig. 1. This apparatus, called the Villard type of transformer unit, employs two condensers and a single rectifying valve. It is noiseless in operation, and has no moving parts. It is capable of producing a maximum voltage of 200,000 with a current of 10 milliamperes. All the intervening voltages between this and 50,000 can be obtained by the turn of a regulator.

Other types of apparatus are available, employing two and even four rectifying valves. These valves have a limited life, and it is worth noting that the greater the number of valves, the greater is the frequency of breakdown. It is the peak of the voltage wave which generates the maximum quantity of X-rays at the anode of the X-ray tube, and the type of apparatus shown has been found to be very effective.

There are excellent self-protected X-ray tubes available of which may be mentioned the "Metalix," "Multix," and "Protexray." These tubes are "self-protecting"—*i.e.*, the X-rays emitted are checked in unwanted directions and only allowed to pass through an aperture situated over the point of maximum X-ray emission. The problem of the protection of the operator is thus simplified, and the operator need only stand with the switch-table behind a leaded screen of suitable thickness during the making of the exposure ($\frac{1}{8}$ in. lead equivalent).

The exposures employed with the aluminium alloys are of short duration, varying from a second at 50,000 volts for sheet metal to two minutes at 200,000 volts for objects 1 ft. thick. The apparatus described can also be conveniently used for X-raying iron and mild steel up to a thickness of $3\frac{1}{2}$ in. In fact, such an outfit has a wide range of usefulness, and can be employed for practically all parts used in aircraft construction.

When thin, flat sheets of alloy are to be inspected, it may be advisable only to employ visual fluorescent screening without making a photographic record. This method, although not as thorough as actual photography, is inexpensive, and only the current expended has to be accounted for. Visual screening is only suitable for showing blow-holes. A machined propeller blade, for example, can be inspected in this way, only the thicker area near the boss requiring radiography (X-ray photography). Its disadvantages are that very small blow-holes, inclusions and cracks are liable to be missed. Actual radiography must be employed where a permanent record is required.

It has been shown in a previous article* that blow-holes as small as $\frac{1}{16}$ in. in diameter can be shown in a mass of alloy up to a thickness of 4 in. It is also important to note that such blow-holes show up best when in the portion of the alloy nearest to the photographic film. The same feature holds in regard to cracks and inclusions. If all such defects have a mass of alloy exceeding 4 in. in thickness between them and the photographic film, their X-ray features are liable to be obscured by scattered radiation from the substance of the alloy.

In order to eliminate the fogging effects of scattered radiation, a Potter-Bucky diaphragm may be interposed between the specimen and the film. This apparatus consists of alternate lead and wooden strips (several to the inch), so arranged that only the direct rays from the tube are allowed to strike the X-ray film. Oblique rays strike the lead strips and are absorbed. Moving diaphragms, as used in X-ray work on the human body, are quite suitable for work on the aluminium alloys (Fig. 2).

Another device for eliminating the scattered rays is the employment of thin lead screens in the X-ray film-holder (Fig. 3). The specimens may be immersed in solutions of barium chloride varying in strength from 17 to 35%, and then taking radiographs. Figs. 4, 5, 6, and 7 illustrate

* Hypher, N. C., *Metallurgia*, vol. 3, No. 17, 159-161.

this method. When using the immersion method, all adherent air bubbles should be removed with a fine brush, otherwise bubble shadows will be mistaken for blow-holes. Finally, there is the method of "blocking." The sides of

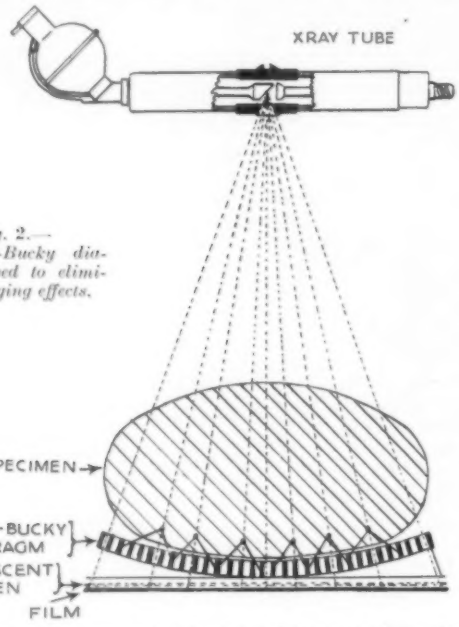


Fig. 2.—A Potter-Bucky diaphragm used to eliminate fogging effects.

the specimen are surrounded by lead foil or barium clay, and all holes filled in with lead shot or barium clay. By this method the scattered rays are "blocked" out and prevented from reaching the film.

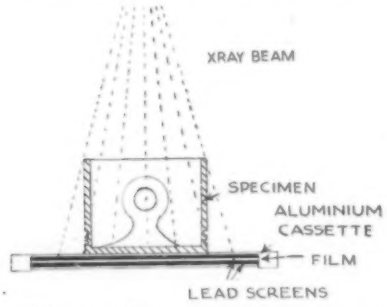


Fig. 3.—Eliminating scattered rays with thin lead screens.

Direct radiography without the use of accessory devices to eliminate scattered radiation may be used with specimens not exceeding 4 in. in thickness. Thus, propeller blades, test-pieces, ingots slices, and rotary fans can be radiographed in this simple manner. With hollow objects such as pistons, tubes, and cylinder heads the same simple

Fig. 4.—Radiograph of specimen taken immersed in 35% barium chloride.

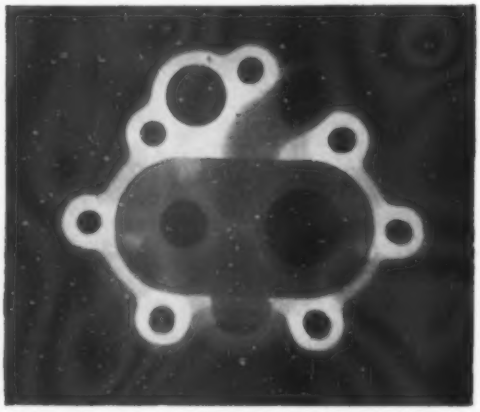


Fig. 6.—Direct radiograph of a specimen showing blowholes before immersion in solution.

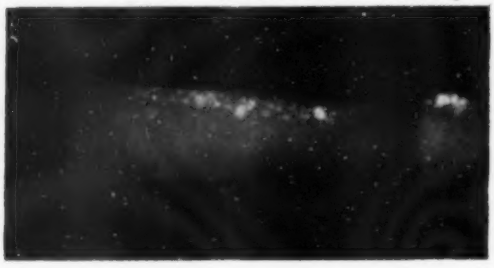


Fig. 7.—Radiograph of same pecimen (Fig. 6) taken immersed in 17% barium chloride.

procedure is efficient so long as the total thickness in the plane of the X-ray beam does not exceed 4 in. A series of Diesel piston castings were subjected to direct radiography of the piston head. Fig. 8 is the radiograph of one which was found by X-ray to be pitted with blow-holes. Sections of the piston-head (1½ in. thick) showed that the blow-holes existed only in the upper "scum" surface.

Where castings have surface pits and scratches, these can be prevented from appearing in the X-ray picture by immersing in barium chloride solution, and making the exposure.

It is frequently a matter for conjecture whether a surface scratch has any depth or is in reality a crack. Here it is advisable to take stereoscopic radiographs, and view the negatives through a stereoscope. The stereoscopic radiographs are obtained by taking two pictures with the same exposure time, but with the tube in two different positions—6 cm. apart,—equivalent to the interpupillary distance between the human eyes. In this way the incident rays strike the object at two different angles, and a crack or other defect is given a three-dimensional position when viewed through a stereoscope. This method is largely employed in human radiography to distinguish between the normal shallow fissures present in the skull and actual fractures.

Specimens submitted for X-ray examination frequently

Fig. 5.—Direct radiograph of specimen prior to immersion.

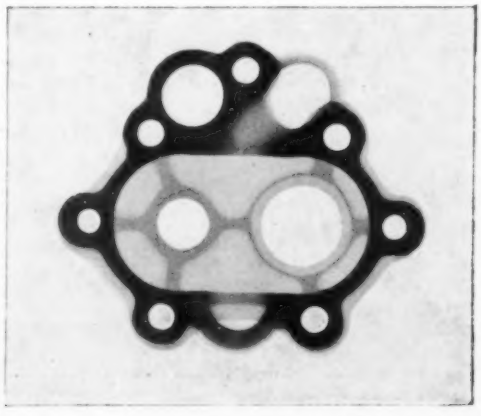


Fig. 8.—Radiograph of a faulty piston-head discovered during the routine radiography of a number of these castings. Note white spots due to blowholes.

possess different thicknesses in the same plane. Several pictures can be taken at optimum exposure times suited to the varying thicknesses, but as this is expensive, one or two exposures of intermediate value should be made and the finished negatives viewed with variable illumination. Thus the thin parts of the object which will be over-exposed can be studied by strong illumination, and the under-exposed sections by a dim light. Viewing-boxes with dimming switches are available, and can be purchased.

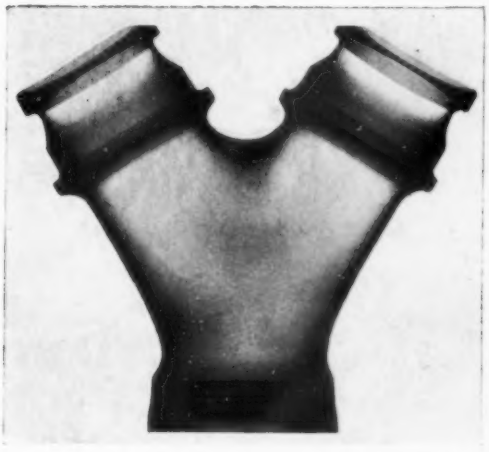


Fig. 9.—Radiograph showing pin-hole porosity in a Y-shaped fire-hose junction.

Skill in interpreting radiographs is just as important, and can be acquired by (1) examining specimens and films side by side; (2) by sectioning specimens; and (3) by comparing the macro surface etchings with the X-ray negatives.

A radiograph of a tubular Y-shaped fire-hose junction is shown in Fig. 9. Pinhole porosity is observable. The etched surface of the specimen showed a "large" crystalline structure. The position and size of the chills in respect to the runners and risers are the determining factors in the production or elimination of this defect.

Aluminium alloy welding offers a special field for X-ray inspection. Particularly is this form of inspection valuable in establishing the proper procedure to adopt with confidence and as a method of checking results, but it is a costly method, and should be used with discretion. When a proper procedure has been found in a given welding operation, and experience gives familiarity in the process the need for X-ray inspection becomes less frequent.

TABLE I.

RESULTS OF TENSILE TESTS CARRIED OUT ON FAULTY SECTION OF A ROTARY FAN BLADE.

Test.	0·1% P.S. Tons/Sq. In.	Ultimate Tons/Sq. In.	Elongation, %.
Longitudinal	9·2	10·40	3·0
Transverse	7·5	9·50	2·0

When a large casting of a rotary fan was radiographed some of the blades showed blow-holes. A radiograph of a faulty blade is shown in Fig. 10. Tensile tests were made on the portion showing blow-holes, in order to see whether the factor of safety allowed for such defects had not been exceeded. The results are given in Table I.

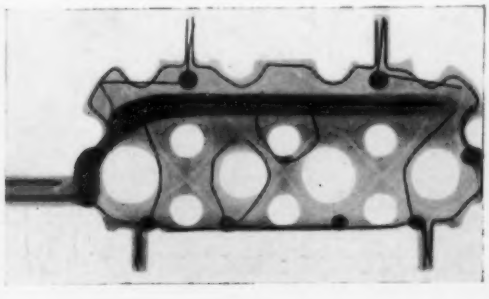
Another practical application of the value of the X-ray is shown in Figs. 11 and 12. In this example the method is used for the detection of faults in the sand cores used in casting processes. The object is to determine whether all cores are similar in manufacture, and also to find the causes of defects arising in the final casting. In Fig. 11 the sand core for the cylinder head of a baby car is shown, while the radiograph of this core, shown in Fig. 12, clearly indicates the disposition of the vents and core wires. The cost of X-ray inspection is often a matter of inquiry. A careful estimate shows that the total costs, including depreciation, labour, current, insurance, rent, developing solutions, and films, works out at 9s. per square foot of film. It should be borne in mind that co-operation is necessary between the metallurgist, foundryman, and radiologist in order to derive benefit from the use of X-ray inspection in the aluminium alloy industry.

Fig. 10.—Radiograph of a blade cut off from the fan. (This blade was selected after the entire fan had been X-rayed). Tensile tests made on the area showing blow-holes are given in Table I.

Fig. 11.—Sand core of cylinder head for baby car.

I am indebted to Mr. W. C. Devereux, managing director of High Duty Alloys, Ltd., for permission to publish this article.

Fig. 12.—X-ray of sand core showing disposition of air vents and wires.



Reviews of Current Literature.

Pulverised Fuel Firing.

THE national advantages of pulverised fuel firing for a wide range of purposes is not yet fully recognised in this country, although in America and on the Continent the system is being increasingly employed. Nevertheless, during recent years its adoption for firing large units has rapidly increased, and this new form of firing has now gained an established position. It is true that the exploitation and adaptation of pulverised fuel to various heating purposes has made great strides in America, but it should not be forgotten that it has been applied to many diverse uses in this country, and the experience built up is undoubtedly based upon the secure foundation of steady and careful progress.

This book concerns primarily the application of pulverised fuel to land and marine boilers. It gives a scientific and economic survey of the development, advantages, and increasing applications of pulverised fuel for steam generation, and incorporates up-to-date information on modern processes of fuel combustion, furnace equipment and dust collection, together with valuable data in tabular and diagrammatic form. A chapter discusses the advantages of pulverised fuel firing for metallurgical purposes, for which it it perhaps understandable that in this country, where many works produce from their furnaces specialised products, considerable caution is exercised before any radical change in fuel application or furnace design is made. It should be remembered, however, that, quite apart from the fuel economy experienced in the utilisation of coal in pulverised form, other benefits which accrue frequently more than offset the extra cost of pulverisation.

The latest application of pulverised fuel firing, as the author states, has been to marine practice, and in view of the fact that it has only been applied during the last few years, and that a new set of problems were involved, striking progress has been made. So far the majority of pulverising installations applied to marine practice have been associated with vessels already constructed, and structural conditions have not been ideal for securing easiest working and highest efficiency.

There is need for engineers to concentrate on the fuel problems involved in a wide range of heating units with the object of making greater and more economical use of coal, and as time and experience prove the reliability and efficiency of pulverised fuel firing, it will be applied to a much greater extent for steam raising, metallurgical work and other purposes for which it has been proved to be especially suitable. Further development of this character would have a considerable influence in promoting a more prosperous condition of one of this country's basic industries, which is so desirable, and power station engineers, marine engineers, designers, and all concerned in the economical and efficient use of fuel will find this book of great value.

By SYDNEY H. NORTH, M.Inst.F. Published by Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London, W.C. 2. Price 7s. 6d. net.

Tin Solders.

IT is not always appreciated how important a part solder plays in our everyday lives. It is one of the most essential and expensive of industrial materials, and although it has been used from primitive times, it is only during comparatively recent years that solders have been given scientific consideration. Solder is one of the most expensive alloys in use in the engineering industry, and yet, until recently, it was frequently purchased in the most slipshod fashion. There can be no doubt that in some instances the same conditions still prevail, but during recent years much has been done to emphasise the need of care in both the purchase and use of solders.

The subject formed part of the early investigations undertaken by The British Non-Ferrous Metals Research Association. It was considered that the study of tin solders and their service requirements offered a particularly favourable field of work, and while reports of these investigations have been published by the Association, this book presents in a more simple form the main results of the investigations for the service of both manufacturers and users of solders. As a direct result of these investigations, British Standard Solder Specifications have been formulated for almost every application in which soft solders can be used, and by adhering to these standards, the buyer and user are safeguarded without in any way interfering with reputable solder manufacturers.

The book is divided into two main parts, the first dealing with theoretical considerations of tin solders, and gives their microscopic analysis and physical properties. It also gives useful information on the strength of typical soldered joints, stressing the factors that influence strength, and revealing the principles involved. The second part is concerned more particularly with the application of solder, and discusses practical considerations, including fluxes, preliminary tinning, spacing the joint members and the wiped joint, and all consideration is given to the choice of a solder, and the various compositions of B.S. grades of soft solder given in a table, together with their physical properties, will be helpful to users as a convenient reference.

The author possesses a gift for presenting facts in a form that is readily understandable, and this book will be of real value to plumbers and tinsmiths, to electricians and cable jointers, and others who have need of solder,, no less than the solder manufacturer. It is admirably prepared and printed, and has an introduction by Dr. R. S. Hutton.

By S. J. NIGHTINGALE. Published by British Non-Ferrous Metals Research Association, Requart Buildings Euston Street, London N.W. 1. Price 5s. net.

Journal of the Institute of Metals—Vol. xlviii.

THE latest issue of the *Journal of the Institute of Metals* contains a record of the recent twenty-fourth annual general meeting of the Institute, and includes the inaugural address of the new president, Sir Henry Fowler, as well as 15 papers of high scientific importance, and the discussions that took place upon these papers. A novel feature of the present volume is the inclusion of a general discussion on "The Testing of Castings," opened by Dr. W. Rosenhain, F.R.S.

The book concludes with a record of Prof. F. Körber's May lecture on "The Plastic Deformation of Metals." Written and illustrated with characteristic thoroughness by the distinguished head of the Kaiser-Wilhelm-Institut für Eisenforschung, Düsseldorf, this discourse constitutes—as the author says, without any mock modesty—"a considerable enrichment of our knowledge of the processes of metal working." The lecture is full of new ideas, and contains explanations of phenomena that have puzzled earlier investigators, whilst it also describes new methods of research. Dr. Körber's contribution is, in fact, likely to rank as a classical contribution to metallurgical literature. It is by the study of such work—enabling, as it does, a complete appreciation of the various valid relationships between stress and deformation to be obtained—that it becomes possible to ensure that the many processes incidental to the industrial working of metals are conducted with the maximum of usefulness. The Institute of Metals is fortunate in its May lecturers who for over 20 years have been enlightening the world of metals through the pages of the Institute's journal.

Edited by G. SHAW SCOTT, M.Sc., F.C.I.S., London: The Institute of Metals, 36, Victoria Street, Westminster, S.W. 1. Price, 31s. 6d.

Standardising Foundry Pig Iron

The production of standard pig irons would tend to simplify the operation, eliminate waste, and promote efficiency of blast-furnace plants. The cost of production would be reduced, which would be passed on to the Foundryman. In this article it is suggested that the adoption of suitable standard grades is long overdue.

AT the present time when the necessity to improve trade is so vital to British interests, it is important that the various trades and industries should unite in the spirit of co-operation to unify, simplify, and modify their requirements by agreement, adopting what is economically best in practice, without attempting to set up an ideal which might be too costly to adopt. Much valuable work in this direction has been effected, and important developments have resulted from standardisation in various industries. Although not by any means a panacea for the industrial depression prevailing, standardisation, properly organised, is an important factor in diminishing the excessive fluctuation of industry, in eliminating much avoidable waste, and in promoting greater efficiency. It is surprising, however, that little effort has been made to standardise the production of foundry pig iron, which offers a field for profitable investigation. The wide range of pig iron specified and the desire for reasonable accuracy in composition, make it necessary that efforts should be directed towards the co-ordination of the requirements of producers and users, through some modified system of grading, with the object of simplifying production and reducing costs.

One of the most effective means of increasing the efficiency of blast-furnace operation is by harder driving and fewer burden changes, and while there has been a distinct tendency to speed up in recent years, there is room for considerable improvement. The fact that foundrymen frequently express the need for pig iron to be made to analysis is not a great difficulty, but when the compositions desired vary almost as much as the orders placed, the manufacturer is justified in complaining.

Each foundryman has his own ideas of what constitutes the most suitable pig iron for his needs, but little or no thought is given to the frequent changes in blast-furnace operation that are necessary in order to meet the individual wishes. Yet the costs of production are considerably increased by these frequent changes, and not the least important is the fact that in changing from one type of iron to another a percentage of off-grade material is inevitably produced of compositions which have a low market value.

Effect of Changing a Grade.

To effect a change of grade in the iron produced by a blast-furnace demands one or more of the following changes in conditions of operation :—

1. A change of ore on the burden.
2. A change in the proportion of iron ore to coke charged.
3. Alteration of the volume of air blast and its temperature.
4. Adjustment of the proportion of flux used per ton of pig iron.
5. Change of the rate of driving (which is also an effect of the above conditions).

The alteration of the silicon, sulphur, phosphorus, and manganese contents of the pig iron, if of any magnitude, demands all of the above changes to a lesser or greater degree. If the grade of iron desired could be obtained at once, such changes would not be so inconvenient. So strict are the specifications, and so narrow the limits of tolerance, however, that a large amount of iron is "off-grade" as a result of each change over. Moreover, there are so many grades of iron in demand, and the quantity of each grade required is so small, in comparison to the hourly output of the average blast-furnace, that it is impossible for one small group of blast-furnaces to meet the demands of the foundry market without frequent changes in furnace working.

In steel-making, it is well known that the number of grades of iron required are very small. Thus, for basic open-hearth work pig iron of low silicon and fairly high manganese is required, whilst for acid open-hearth the demand is for iron containing moderate silicon and manganese. Where steelworks iron is manufactured, therefore, the blast-furnaces concerned may run more economically and with greater regularity.

For economical reasons the modern tendency in blast-furnace practice is to use larger furnaces of very high daily capacity. Furnaces of 1,000 tons per day are now becoming common. When it is realised that such furnaces depend for their economies upon high hourly rates (in this case about 40 tons per hour—160 tons per cast), and that a change of grade may mean anything from 400 to 1,000 tons of off-grade iron, the position will be appreciated.

Benefits of Standard Grades.

Reducing the number of grades of pig iron in demand, by standardisation of analyses would confer benefits on the foundryman as well as upon the manufacturer, since the compositions would be more reliable, and, on account of lower production costs, the pig iron would be cheaper. Such standardisation would result in the production of a more limited range of ordinary commercial grades that would be a benefit to producers of comparatively common or simple castings. The method would not interfere with the skill of competent foundrymen who are able to mix their iron and control remelting in the cupola so as to improve its quality for such purposes as a higher quality iron is desirable. But it might be possible to adopt more flexible methods of refinement at the foundry, after the iron has been remelted in the cupola, by using a mixer such as is used in some steelworks. Such a procedure would result in producing a more consistent melt, whose composition would be controlled easily at will.

High-duty Cast Irons.

Considerable progress has, however, been made in the development of cast irons to meet service conditions, which some castings are now required to withstand. In order to comply with these conditions, the chemical composition alone is not a sufficient guide to the quality of the iron, and complicated tests on inherent strength properties have to be undertaken in order to ensure that the material is suitable for the purpose for which it is to be used. In order to meet special needs of this kind, the production of refined pig iron is being developed. Many expert foundrymen, particularly those who are metallurgists or who have the facilities afforded by an adequately staffed metallurgical laboratory, carry out their own refining and produce special remelted iron to meet their special needs, but the production of refined pig iron, capable of meeting the increasing needs

of industry, is becoming more and more a specialist's job, in which technical control is of paramount importance.

The market for special pig irons of various kinds is now, and probably always will be, limited in comparison with the demand for ordinary foundry qualities, which can be produced at a cheap price, and because of the limited demand it can be best handled by those specialist firms who have the knowledge and resources to conduct the trade on economic lines. The tendency during recent years of driving the blast-furnace harder with fewer burden changes may be attributed, in part, to the necessity for refined iron to meet an increasing variety of high-duty purposes.

There is, of course, a distinction between common pig iron and refined pig iron at the present time, but by standardising the grades of ordinary foundry qualities on the one hand, and having available suitable refined pig iron for special purposes, it would tend to eliminate waste and promote efficiency. By the adoption of standard pig irons the blast-furnace plants of the country would be able to produce the grades of iron for which they are best suited as regards natural resources, and to produce these grades at the maximum of output and the minimum of cost. This would be possible because the manufacturer, being confident of the ultimate consumption of his stocks, could produce quantities of each grade in batches larger than is economically possible or desirable under the present system, in which iron must be manufactured of a composition differing from day to day.

The demand for special irons would, of course, be met by a limited number of producers of these irons in various parts of the country, and while it is inevitable that these special irons, which have to undergo a refining process, would be more expensive, the tendency would be for the common grades to be produced cheaper and would meet the more general needs. Special or refined irons would be used for high-duty castings, where, generally speaking, the conditions in service would be more important than the first cost of material. Under such circumstances the higher prices which would be paid for such irons to ensure the right quality would easily be justified.

The question of what might be regarded as the most suitable standard grades to meet general conditions would provide ample scope for co-operation between pig-iron manufacturers, foundrymen, and metallurgists, and it should be possible to arrive at amicable decisions which would eliminate some of the problems that retard the economic development of blast-furnace practice.

Wire: Machine and Single-Hole Drawing

By Richard Saxton.

The author compares machine and single-hole wire drawing, and discusses their effect on the product.

ALTHOUGH the reduction of iron and steel by drawing was first commenced in this country over 100 years ago, the adaptation of machines to replace the then universal single-hole system was not accomplished until 1900, when R. P. Slinger introduced the first successful machine to reduce in two holes or drafts at the one operation. Further experiments extended this method to four and five reductions at one operation, but the four-hole machine is the chief type in use to-day.

While machine drawing has undoubtedly proved a big factor in increasing output in wire manufacture, research and experimental work have exposed its limitations, and for drawing high-strain qualities of wire it is practically of no service. This is due to the fatigue stresses set up by the reducing process, these having the effect of making the material extremely brittle, and which it is only possible to eliminate, apart from annealing, by allowing the material to rest. These stresses are also met with in the single-hole system when drawing high-strain material, but here it is the practice to allow the wire to rest for at least one hour before proceeding with further reduction. The resting period is not possible in machine drawing, and it is the rapid reduction, combined with the hardness of this particular material, which gives an objectionable effect to the quality. Without allowing this resting period, it is impossible to produce wire in the quality required for pit winding ropes.

While the machine-drawn product fully answers the purpose for which it is intended, and is of good quality in its class, it can never rival the quality of that of the single-hole drawn material, or be as ductile. The more rapid reduction, the lack of time to recover before undergoing further reduction, both exert an effect which produces a material of a less malleable nature. As an offset against this there is the increased production of the machine, which, with a four-holer, is practically four times as great while the machine is running, but which in actual practice works out to about 150% increase. The loss is due to the time taken in threading-up the machine preparatory to starting.

An advantage which the single-hole machines possess is the means to draw the wire the reverse way—that is, to take the last or thicker end and draw first. This process of reversing when finishing the wire often means the difference between good and bad material, as its action relieves the pressure on the grain caused by previous reducing.

The bulk of the material drawn on machines has a carbon content of from 0·10 to 0·15%, and steel of this quality presents little difficulty in reducing for about six holes, equalling roughly about nine sizes. Drawn beyond this the material hardens up, and is quickly in a state known as over-drawn—a condition of extreme brittleness.

With the single-hole system, steel containing a carbon content as high as 0·9% can be drawn successfully, giving a breaking strain up to 135 tons per sq. in. In this class of wire—110 to 135 tons tensile strain,—chiefly manufactured for pit winding ropes, the torsion is a more difficult and important matter than the tensile strain. If found too low, the latter can easily be raised by varying the drafts in the reducing process, but the correct torsion properties can only be achieved by strict attention to the elimination of fatigue stress. There are, of course, other matters which affect the torsion, such as defective heat-treatment, but we are here dealing with those defects produced in the drawing process.

In conclusion, many people connected with the wire industry consider the torsion test as one indicating ductility. This is wrong, for bad wire at times will give a good test. The true function of this test is to determine whether the quality of the wire is uniform. Good quality shows regularity of twist, hardly perceptible to the touch, and poor quality is indicated by irregularity during torsioning, the twists showing first at one end and then the other while the sample is being tested, instead of forming in an even manner.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part XIII.—Finish Rolling.*

Brief consideration is given to recent, and probable future, tendencies in rolling methods as influenced by consumer demands for close gauge tolerances, and necessity for reducing labour costs of finish rolling. In this connection some experiments carried out to determine the feasibility of rolling wide aluminium strip on four-high continuous mills are described.

Experimental Rolling of Wide Strip.

As is well known, broad steel strip has been produced of recent years by hot and cold rolling on four-high mills. This product approximates sheet in width and strip, in length, and in gauge ranges. The engineering aspects of producing steel sheet in strip lengths have been discussed rather fully in rolling-mill literature and need not be taken up here. From the economic point of view labour costs are greatly decreased by finishing sheet (as wide strip) on four-high tandem mills, as compared with the usual finishing on two-high mills. In the matter of gauge, exceptionally uniform thickness across the width can be attained in wide strip (sheet widths) rolled on four-high mills. Sheet finished on two-high mills is generally heavy in the centre, and the control of conditions necessary to produce uniform gauge is difficult.

Some tests were carried out about four years ago to determine the behaviour of aluminium when processed on four-high mills, such as are used for the cold-finishing of broad steel strip. A resumé of the experiments is given below.

The rolling was done on a four-stand installation of four-high tandem mills at the plant of a steel company. Fig. 7 shows a four-high mill of the type employed in the experiments. The working rolls of the mills used were 16 in. in diameter, and the backing-up rolls were 32 in. in diameter; the working width was given as 36 in. (for finished stock), but material somewhat wider could be finished. Rolling tests were made on slabs of 99+% aluminium, 36 in. wide, $\frac{1}{8}$ in. to $\frac{1}{4}$ in. thick, and about 30 in. to 60 in. long. Some slabs were rolled to 16-gauge, or to 18-gauge, on being passed through the four stands. Others were run to the same gauges on being passed through the last two stands. One slab was rolled from $\frac{1}{8}$ in. thick to 16-gauge on a single pass through the last stand. All the rolling was done at room temperature.

The results obtained in these tests were good, indicating that wide aluminium strip of uniform gauge can be produced on four-high mills. Most of the strips were badly buckled and waved, so badly, in fact, that the ordinary flattening operation on a roll leveller was ineffective. None of the sheets was pulled in a stretcher. The buckling was ascribed to the centre fullness of the rolls, these having been ground with a crown of about 0·003 in. This doubtless caused some pinching. The indications are that the rolls should be ground flat, or possibly slightly hollow, in order to secure satisfactory results with aluminium. Rolls ground with a slight concavity have been used for finishing steel strip.

Table II. gives the data recorded in rolling an aluminium slab from $\frac{1}{4}$ in. thick to 0·055 in., the stock being passed through the four stands in succession. The thickness at the centre, after the individual passes through the first three mills, could not be measured except at the dragged-out (thinned) ends; no means were available for shearing these ends so as to measure the centres farther back. After the last pass an end was cut off by shearing, and the thickness at the centre was measured at a distance of a couple of feet along the length from that end.

* (*Continued from July issue, page* 86.)

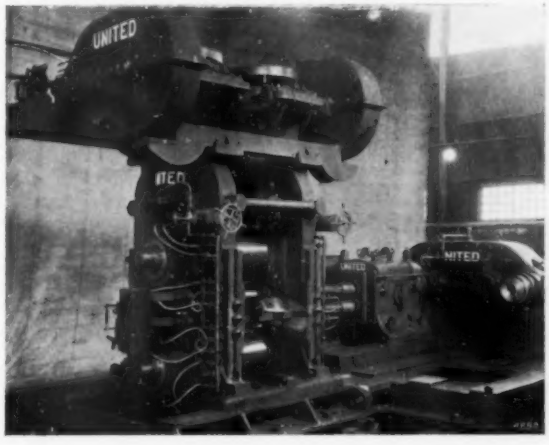


Fig. 7.— Four-high strip mill (United Engineering and Foundry Co.)

TABLE II.

Data Recorded in Rolling an Aluminium Slab on Four-high Mills.

Condition.	Thickness, In.			Length, In.
	Right Edge.	Centre.	Left Edge.	
Original slab	0·270	0·278	0·266	29¼
After first pass	0·200	—	0·204	41
After second pass.....	0·135	—	0·136	61⅜
After third pass	0·105	—	0·103	79
After fourth pass	0·055	0·055	0·055	144

TABLE III.

Data Recorded in Rolling an Aluminium Slab on Four-high Mills.

Condition.	Thickness, In.			Length, In.
	Right Edge.	Centre.	Left Edge.	
Original slab	0·193	0·199	0·193	35
After first pass	0·138	—	0·144	48¾
After second pass.....	0·105	—	0·105	65
After third pass	0·090	—	0·093	73½
After fourth pass	0·043	0·043	0·043	154

Table III. gives the data recorded in rolling an aluminium slab from about 0·2 in. thick to 18-gauge, the stock being passed through the four stands.

Table IV. gives the data recorded in rolling an aluminium slab from about $\frac{1}{8}$ in. thick to about 17-gauge, the stock being passed through the last two stands. As may be noted, one edge was heavier than the other. An end was sheared off after the first pass and the thickness at the centre measured.

On rolling a slab $\frac{1}{8}$-in. thick to about 16-gauge on one pass through the last stand, the stock cracked at the front end and at one edge. The thickness measurements were as follows, after the pass: Right edge, 0·053 in.; centre, 0·055 in.; and left edge, 0·052 in. Evidently the draft was too great, and the thickness was, consequently, not uniform.

The speed of the mills was as follows: First stand, 28 r.p.m.; second stand, 32 r.p.m.; third stand, 35 r.p.m.; and fourth stand, 38 r.p.m.

While the conditions surrounding these experiments were rather unsatisfactory, the results show that aluminium can be rolled on four-high mills with heavy drafts and uniform gauges produced. The four-high mill has distinct potentialities in aluminium practice, but so far it has been employed very little in the production of commercial aluminium sheet. It appears also that the four-high mill would be well adapted to the finish rolling of wide duralumin strip for use in aircraft construction—*e.g.*, wing covering.

Finish Rolling of Alloys.

The general methods of finish rolling, which are employed in the production of aluminium sheet and coil, are also employed in processing the corresponding aluminium-alloy products to final gauge. Of course, the alloys are all harder and less ductile than aluminium, and, consequently, cannot be deformed so easily. However, the soft alloys can be readily worked and present no special difficulties other than those encountered in rolling the substantially pure metal. Soft alloys, such as 3 S, 51 S, and the 95 : 5 aluminium-silicon composition, may be finished with about the same rolling practice as is employed for 99+% aluminium. In dealing with the hard alloys—*e.g.*, duralumin—drafts are to be decreased markedly, and passes increased in order to prevent cracking and surface checking.

TABLE IV.
DATA RECORDED IN ROLLING AN ALUMINIUM SLAB ON FOUR-HIGH MILLS.

Condition.	Thickness, In.			Length, In.
	Right Edge.	Centre.	Left Edge.	
Original slab	0·126	0·131	0·124	61¼
After first pass	0·100	0·104	0·105	75¼
After second pass.....	0·046	0·044	0·044	176

So far aluminium-alloy sheet and coil have been largely rolled on mills designed, or originally purchased, for rolling aluminium. In processing duralumin, it is likely that more satisfactory results would be secured if the material were rolled on mills especially designed for hard metal. In any case, duralumin should be finished on forged alloy-steel rolls rather than on the ordinary chilled cast-iron rolls. Aluminium-alloy sheet is usually rolled in the bright finish. When duralumin sheet is heat-treated by soaking in a molten salt bath prior to the quench the surface finish is dull and greyish in colour. The 3 S alloy is produced in the grey-plate finish, usually in the heavier gauges. The surface finish on aluminium-alloy coil may be slightly dull (similar to the usual finish obtained on aluminium coil, rolled with oil on cast-iron rolls) or bright. Soft alloys which are not heat-treated may be furnished in the bright finish in any temper. Annealed or hard-rolled duralumin may be furnished in the bright finish. When duralumin is water-quenched a bright surface finish is stained and dulled, so that the heat-treated material does not carry the bright finish. Of course, a stained surface may be polished if desired. If duralumin sheet or coil, which has been quenched, is given some passes, either before or after ageing, the surface will be brightened.

In the finish rolling of duralumin flat sheet, heavy-gauge material, say No. 12-gauge, may be run directly from annealed slabs, which have been roughed to about 0·18 in. thick. Sheets to finish at about 20-gauge and heavier (down to 14-gauge) may be run from annealed stock which has been roughed to about 0·08 in. thick. Sheets to finish lighter than 20-gauge may be run from annealed stock which has been roughed to about 0·04-in. thick. These thickness limitations apply also in the finish rolling of duralumin coil. Cracking in from the edges is much more serious in rolling duralumin than is the case with aluminium and the softer alloys. Cracked edges or ends are trimmed whenever necessary to stop further cracking. On account of the tendency to cracking and surface checking, the recovery of acceptable material is considerably less in processing the harder as compared with the softer alloys (or aluminium).

In the next article of this series the various types of rolling mills used in practice for the cold working of aluminium-sheet products will be described.

Grain Size, Eutectic, and Corrosion of Lead.

FURTHER data, presented by M. Werner,* confirm the conclusions made in an earlier investigation into the corrosion of lead. At that time the following facts were stated: (1) The grain is to be as small as possible. Metal additions which enter the mixed crystal enlarge the grain. (2) The local elements formed when foreign crystals are present may prevent or promote corrosion according as they form passive layers or soluble corrosion products on the lead. (3) A large grain can be refined by the addition of other metals, provided that they are precipitated as separate crystals. The local elements thus formed have a favourable effect only in the case that no large quantities of eutectic are formed.

Recent grain-size measurement gave the following results: The average grain size of electrolytic lead after being compressed by 50% and annealed at 180° C. for 24 hours, was 0·076 mm.² Adding 0·0014% of bismuth enlarged the grain to 1·57 mm.²; further additions had no effect. 0·0045% of nickel enlarged the grain to 0·3 mm.² On the other hand, 0·009% of nickel markedly refined the grain, the average size being 0·045 mm.² This fact shows that electrolytic lead still contains small quantities of impurities, which form nickel compounds insoluble in lead. Works lead containing 0·0075% of bismuth had an average grain size of 0·916 mm.² Further bismuth additions enlarged the grain in a different degree, the largest size found being 1·88 mm.² 0·0045% of nickel markedly refined the grain, the average size being 0·043 mm.²—that is, half as large as that of electrolytic lead. The author is of opinion that with the aid of grain-size measurements it might be possible to determine the solubility curves, because the grain is enlarged with increasing percentages of the other metal until the curve is reached, and refined when the solubility limit is exceeded. Further, when the solubility curve is fixed, the percentage of the other metal in a super-saturated solution can be determined by diluting the alloy with pure lead.

The question whether the local elements have a beneficial or harmful effect is decided by the potential difference which the additional metal shows in the corrosive agent in question. Thus, it was found that in concentrated sulphuric acid of 20° C., nickel is nobler than lead by 0·78 V., which explains its beneficial effect upon the resistance of lead to the action of the acid mentioned. However, a metal, though nobler than lead, has a detrimental effect when it forms a eutectic with the lead, as do silver and arsenic. If, however, such metals are mechanically added—or by hammering-in chips or by rolling-in the metal after having been electrolytically deposited,—they increase the acid resistance. This process is covered by patents.

The grain-enlarging effect of metals which enter the mixed crystal was also found with copper alloys after having been compressed by 50% and annealed at 800° C. for 24 hours. Zinc, tin, and iron markedly enlarged the grain—*e.g.*, 0·5% Fe from 0·104 to 2·667 mm.² After exceeding the solubility limit, a considerable refinement took place. Thus, 3·5% Fe gave an average size of 0·233 mm.²

* *Zeitschrift fur Metallkunde*, 1932, pp. 85-87.

Recent Developments in Rod and Wire Mills

By Albert Nöll.*

Abstract of Report No. 93 of the Rolling Mill Committee of the Association of German Ironmasters.

CONSIDERABLE progress has been made in the direction of bringing the auxiliary plant at rolling mills into line with the developments which have already taken place in the design and construction of the mills themselves. Especially has this been so in connection with cooling beds, which constituted a bottle-neck in the production of rods and small sections, as shown by the large number of new equipments and reconstructions in recent years. The basis of the various designs has been increased output—*i.e.*, reduction in production costs, as a result of which cooling beds have arisen with several times the capacity of earlier types. A further point to which attention has been given is that of increased yield, by reducing the loss from scrap ends and odd lengths. The latest steps have been in the improvement of the product as regards straightness and even quality due to regular cooling.

The rolling of a number of rods at the same time, greatly increasing the output of the mill, introduced special difficulties when these were delivered into a common trough. The temperature differences caused unequal contraction, and also uneven expansion in passing through the re-crystallisation range, which led to distortion of the rods. The first stage in the development consisted of the use of separate troughs, but the manner of transfer to the cooling bed left much to be desired, and special arrangements have been adopted to secure, as far as practicable, individual handling of the rods, without risk of bending or twisting due to dropping or rolling over.

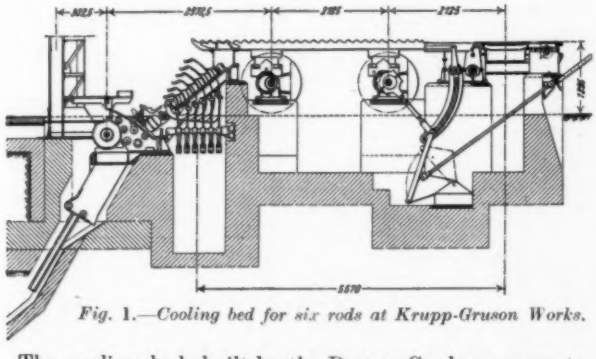


Fig. 1.—Cooling bed for six rods at Krupp-Gruson Works.

The cooling beds built by the Demag Co. have separate troughs arranged either vertically or at an angle above each other. The rods are delivered into these by means of conical discs mounted on a common motor-driven vertical or inclined shaft. In the vertical arrangement the channels are enclosed on all sides, the removal of the rods being effected by raising the front wall. With the inclined arrangement the channels have an open side. The rods are lifted one after the other out of the channels by a withdrawing gear, operating at definite intervals, which places them on the bed on its return stroke. A cooling bed for six rods, being built by the Krupp-Gruson Works, is shown in Fig. 1. This has also separate pockets for each trough, from which the rods are lifted by an auxiliary gear and placed in a common groove in the rack cooling bed. The individual troughs are controlled automatically or by hand. It must be mentioned here that the automatic control has not yet proved fully capable of meeting works requirements, particularly in regard to the length of the hot rods. In this connection the electrical control of the shears by relays operated by short-wave radiation from the hot bars appears very promising.

An American cooling bed for flats and rounds is shown in Fig. 2. In this case the flat bars are mostly of spring steel, for which it is desirable that the cooling should be slow and as far as possible uniform. The flat bars are therefore placed on edge, close together. By this means cooling takes place slowly, and the bars are only laid flat on the transfer gear after reaching a definite stage of cooling. With rounds the stacking gear is put out of action. In view of the many designs which have been produced within the latest period, it may be assumed that the development of cooling beds is still far from being at an end. The direction to be followed is dictated by the demands for better quality and higher output.

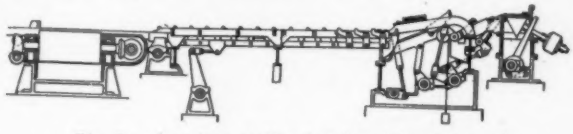


Fig. 2.—American cooling bed for plots and rounds.

In considering the installation of new rolling mills the question always arises whether to employ an open-type mill with loops between successive passes, a semi-continuous or a continuous mill. The advantage of the open-type mill in regard to the production of exact shape and dimensions is great, against which must be offset the great differences in finishing temperature throughout the length of the wire rod, and the limitation in the weight of the coils. The effect of variation in temperature is often underestimated. With higher carbon steels it can lead to quite large differences in the strength and microstructure along the rod. An experimental rolling of a 110-kilogs. (242 lb.) coil of 5 mm. dia., rod of 0·51% carbon steel showed a variation from 1,020° to 600° C., a drop of 420° C. from start to finish of the last pass. Nine test-pieces, cut at regular intervals from the rod, showed differences of 10 kilogs. per sq. mm. (6·35 tons per sq. in.) in the tensile strength, and of 21 kilogs. per sq. mm. (13·3 tons per sq. in.) in the yield point, with corresponding differences in the elongation and reduction of area.

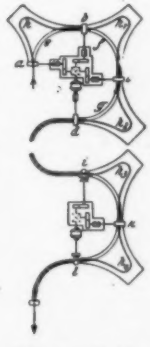


Fig. 3.—Guide arrangements for removal of tension between passes.

Recent proposals aiming at securing the advantages of the continuous mill have been based on the complete removal of the tension between passes, by a suitable arrangement of the stands which permits the formation of small loops after both the oval and square grooves, without requiring special auxiliary gear. Examples of such designs are shown in Fig. 3. The central location of the drive reduces the cost of the plant, whilst the stream-line shape of the short channels enables the formation of the loops without trouble or interruptions.

* *Stahl und Eisen* 13 *and* 16, 1932, *pp.* 305-309 *and* 381-389.

The reconstruction of the semi-continuous rod mill of the Niederrheinische-Hütte, Duisburg, was undertaken to enable the production of coils weighing up to 200 kilogs. (441 lb.) without disturbing the existing mill. The minimum output of the new portion was to be 16 tons per hour of 5 mm. dia. rod, so that with the whole plant in operation the production per month would be at least 22,000 tons of rod. It was also required to produce thinner rod. An important condition was that both sets of rolls could be worked independently or at the same time. The old mill, Fig. 4, was equipped with three pusher furnaces, from which

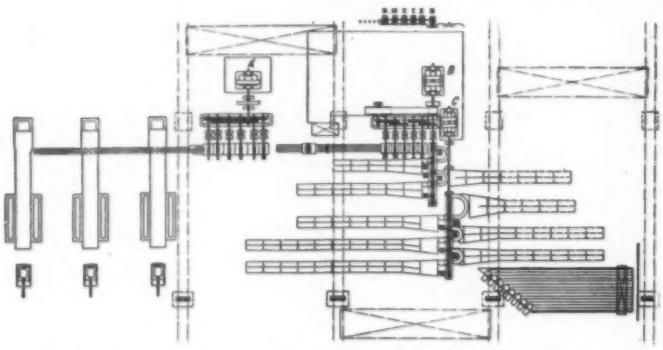


Fig. 4.—Layout of the old mill of the Niederrheinische-Hutte, Duisburg.

the billets, 130 mm. square, were taken by a roller path to the No. 1 continuous roughing mill, having six stands with rolls 410 mm. dia. by 900 mm. long, driven by a 1,600-h.p. motor. The reduced billets, 40 mm. square, were cropped and cut into suitable lengths by two shears. These billets were passed in two strands side by side through the No. 2 continuous roughing mill, having six stands with rolls 350 mm. dia. by 900 mm. long. This roughing mill and the No. 1 finishing mill were driven by a double commutator variable-speed direct-current motor of 3200 h.p. (300 and 500 r.p.m.) The No. 1 finishing mill consisted of four stands with rolls 325 mm. dia. by 800 mm. long. The No. 2 finishing mill had six stands, with rolls 260 to 290 mm. dia. by 800 mm. long, direct driven by a 2,800-h.p. motor with speed variation from 500 to 620 r.p.m. The finished rods, 8 to 13 mm. dia., were wound on eight swifts placed in a row at an angle of 45°, as shown, at the end of the cooling bed.

The arrangement of the new mill with the reconstructed mill is shown in plan and elevation in Fig. 5. The No. 1 roughing mill remained unaltered, the motor being rewound

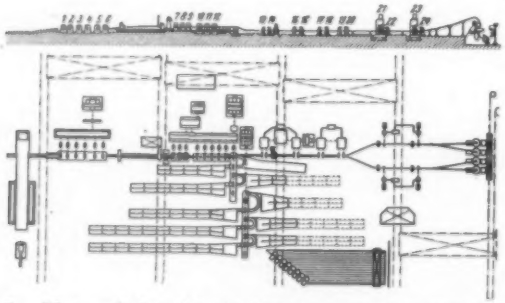


Fig. 5.—Plan and elevation showing arrangement of new mill with reconstructed mill.

to increase the power to 2,180 h.p. The strands left the last stand of the original No. 2 roughing mill with a section of 12·5 mm. square at a certain speed which could not be altered, since the high output of the existing mill had to be maintained. In order that the finishing speed of the new mill should not exceed 23 m. per sec. (4,530 ft. per min.), it was found necessary to combine the last stand of the new No. 2 continuous roughing mill with the old ninth stand. The first three stands of the original No. 2 roughing mill were therefore moved forward and raised up to form the first three stands of the new No. 2 roughing mill, and replaced by three special four-high stands. The lower pairs of rolls of the latter serve as stands Nos. 7, 8 and 9 of the original mill, while the upper pairs serve as stands Nos. 10, 11, and 12 of the new mill. A variable-speed 2,000-h.p. motor was installed to drive the new No. 2 continuous roughing mill and the first three stands of the old one.

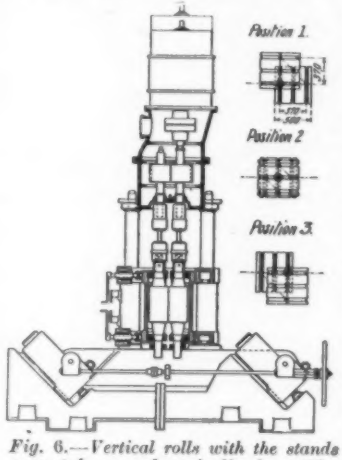


Fig. 6.—Vertical rolls with the stands mounted on a plane inclined at 45°.

In spite of the high finishing speed of 4,530 ft. per min., the rolling time for the 441-lb. coils is about 70 secs. In order to prevent the cooling of the billets they are passed through a double channel covered trough, heated by coke-oven gas placed in front of the new No. 2 roughing mill.

From the No. 2 roughing mill the rods pass in two strands into the new No. 1 finishing mill. This consists of eight stands with rolls 280 mm. dia. by 820 mm. long, of quite novel design. The stands are arranged in pairs, the distance apart of which is only about 1 m. (39½ in.), the rod between them being oval in section. The mill is driven by a 2,000-h.p. motor, the speed of which can be regulated in the ratio of 1 to 11. The pinions and driving gear for each pair of stands are mounted in a special casing, forming an oil-bath, the oil being circulated under a pressure of 115 lb. per sq. in., continuously filtered and cooled in an oil cooler. The bevel gears have spiral teeth, giving very uniform and noiseless running. A novel cropping shear, with rotating cast-iron anvil fitted with a tyre, is placed after the first pair of stands. Above the anvil there are two slots carrying stamps with knives which fall and crop the rod when a trip is released.

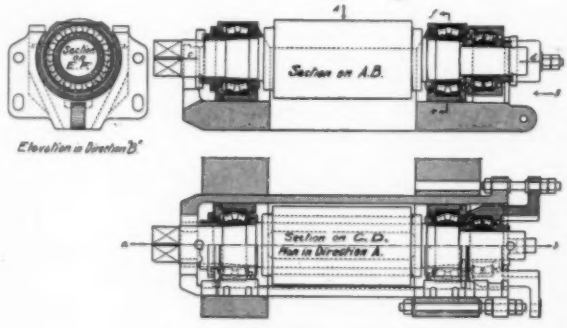


Fig. 7.—Self-aligning bearings.

The design of the No. 2 finishing mill is on completely new lines. Since perfect rods can only be produced when only one strand passes through the finishing rolls, this mill consists of duplicate sets of four stands, arranged side by side, as shown.

With the high finishing speed the use of twisting guides for the oval section would result in excessive rubbing away and lack of roundness in the finished product. It was therefore decided not to twist the rod but to place the oval passes in vertical rolls. Further, the hot, thin rod at these high speeds should not be diverted out of its straight path. In order to effect this, and at the same time use all possible

(*Continued on page* 127.)

Electric Resistance Alloys for High Temperature Service

Metallic resistors are largely used for temperatures up to 1,000°C. Their increasing application is due to improved technique in the production of suitable alloys for the purpose. In this article alloys for high-temperature service are discussed and data is given. Some of the statements made in the article may not be generally accepted, but an endeavour has been made by the writer to discuss the subject without prejudice or bias. It must be borne in mind, as our correspondent points out, that while the alloys produced by the different manufacturers are similar, they are not exactly the same, and the claims made for the alloys by different manufacturers differ in detail.

DURING recent years electric energy has come into wide use as a source of heat for many purposes. Its increasing application in industrial heating operations is due in no small measure to improvements in the production of suitable resistors which are embodied in the resistor-type furnace. The principle of obtaining heat in these furnaces is by passing the electric current through resistances, which constitute the elements, and since the successful operation of a furnace is largely dependent upon the quality of the resistances used, care must be exercised in their selection in order that they will give long service at temperatures desired.

The production of these resistances has involved much research work, and experimental investigations have been in progress for many years, perfecting suitable materials for the purpose. Investigations have been carried out on metallic and non-metallic materials with the object of developing commercial products that would maintain a high resistance against the influence of atmospheric air under high temperatures. In addition to heat-resisting qualities and resistance against chemical agencies, a high specific resistance is necessary to enable the resistances to accommodate themselves readily to various line tensions and apparatus.

Much development has been made in the production of non-metallic resistance materials, notably those that consist primarily of silicon carbide, but in practice more general use is made of metallic resistors for temperatures up to 1,000° C., and it is due largely to improved technique in the production of suitable alloys for this purpose that they are finding increasing application.

Of suitable alloys for electric resistance heating, the most important are the binary series of nickel-chromium alloys and the ternary series of nickel-chromium-iron alloys. These alloys possess remarkable heat-resisting qualities, but it is not due to their heat-resisting qualities alone that they are valuable for electric heating purposes. It is the property they possess of resisting oxidation at high temperatures which gives them high value as resistors. This property, however, is influenced to a considerable extent by impurities in the alloys, even the presence of very small amounts, according to Smithells, Williams, and Avery,[1] has a marked effect in lowering the resistance to oxidation. It is for this reason that manufacturers have concentrated on the production of commercially pure alloys and in increasing the resistance to oxidation the alloys give more effective service at higher temperature limits.

The impurities that influence the quality of these alloys are sulphur, carbon, and oxygen. In the binary alloy manganese is usually added to overcome the effect of the sulphur present and to act as a deoxidiser, but its presence has the effect of lowering slightly the melting point of the alloy. If carbon is present during the melting of the alloy it may be dissolved and precipitated into irregularly spaced masses which result in the formation of areas of higher electrical resistivity, and in certain cases the superficial disintegration or cracking of the element. Both these defects seriously reduce the working life of the element, and are the cause of many premature failures. Oxygen may be present in the form of chrome oxide, and, unless removed from the melt, will have a detrimental effect on the alloy.

Greater purity in the manufacture of these alloys results from the use of materials commercially free from carbon and from adopting modern melting practice. The development of the induction furnace has enabled manufacturers to improve production methods and give an alloy almost free from impurities. The microstructure of a forged 80–20 alloy produced in this way is shown in Fig. 1. The finely equiaxed crystalline structure of the alloy and freedom from deleterious impurities is clearly shown.

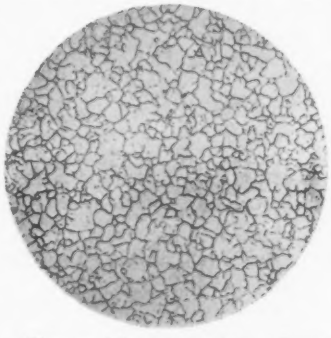


Fig. 1.—Microstructure of forged 80-20 alloy. By courtesy of Wild Barfield Electric Furnaces, Ltd.

The melting operation demands specialised skill and care, and the subsequent operations certainly require no less. The ingots on reaching the hammer or cogging mill have a perfectly continuous surface, no flaw or blemish remaining. If any previously invisible cracks, etc., appear later they are, of course, removed. The billet is then hot-rolled to ¼ in. rod, annealed, and cleaned.

The grooves in the rolls must be maintained in first-class condition in order to prevent any unevenness of the rod, as this effects the surface of the drawn wire, and a smooth and uniform surface is a prime essential of these wires.

It is customary to clean off any oxide which forms during processing, since if this be drawn in early scoring of the dies results, and the outer surface of the wire may lack uniformity. Pickling is resorted to for this purpose, but this, too, particularly if frequently carried out, by producing a rough surface, tends also to produce "layering" under the surface of the wire, and hence to affect the adherence and cohesion of the protective coat subsequently formed. Bright annealing is of obvious value in avoiding these difficulties, and is now employed to a considerable extent in this industry.

After cleaning, the process is one of wire drawing adapted to the special requirements of these alloys. The weights of material which pass through a die before it "pulls out" are trifling compared with those which would be obtained in iron and steel wire. This is due, firstly, to the refractory nature of the alloys, and, secondly, to the importance of accurate size and shape. Alloy steel dies are used for the heavy sizes, diamonds being obviously impossible, but diamonds are used exclusively for the finer sizes.

1 Smithells, Williams, and Avery, *J. Inst. M.*, 1928, 40, 269-290.

In the cold rolling of these alloys the same wear and tear is encountered. Only the very highest class of steel roll is of any value at all for this work, and constant regrinding to a brilliant mirror-like surface is essential. Even so, the output of some of the finer sizes between regrindings is a matter of ounces.

The resistance to oxidation, which is one of the most valuable properties of these alloys, is difficult to measure, and it is generally difficult to compare the results of different investigators using different methods of testing. Probably the most systematic work in this field is that of Rohn,[2] who compared the oxidation resistance of nickel-chromium alloys containing 10, 15, and 20% chromium, and nickel-chromium-iron alloys containing 15 to 33% chromium.

The alloy containing 80% nickel and 20% chromium has been found to be the best of the binary series in practice. According to the degree of purity, the conditions of service and the method of mounting, this alloy may be used at temperatures up to 1,150° C. Reducing the chromium content to 15% slightly raises the melting point, but reduces the temperature at which the alloy will give effective service, whereas an increase in the chromium content to 30% presents production difficulties which considerably increase the cost of rod, wire, or ribbon, into which these alloys are manufactured for electric-heating purposes.

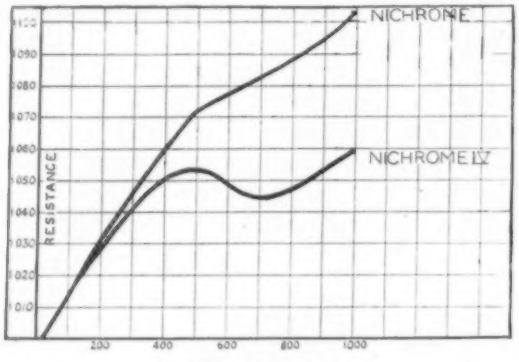


Fig. 2.—Change of resistance with temperature.

It should not be assumed that no oxidation takes place when the bright surface of 80–20 nickel-chromium alloy is subjected to high temperature in the presence of air; actually, the alloy is immediately covered with a very thin layer of oxide, but this coating has the unique property of resisting the penetration of oxygen and thus prevents further oxidation taking place, or at least making the rate at which the layer of oxide increases in thickness very slow indeed as long as the protective coating remains on the alloy. It is therefore essential that the oxide coating originally formed should adhere under normal working conditions of the heating appliances in which the alloys are used. This subject formed part of the investigation by Smithells, Williams, and Avery, to which reference has been made, in which it was shown that in the case of the 80–20 alloy the oxide coating is thin and adherent. Once formed, its increase in thickness is very slow. These research workers found that this protective type of oxide contains a larger proportion of chromic oxide than is present in a non-protective oxide, and that at least 50% chromic oxide must be present in order to obtain satisfactory results.

In the case of the nickel-chromium-iron series of alloys, the alloy containing 65% nickel, 15% chromium, and 20% iron is a useful one for all-round service. Any further increase in the iron content, although raising the specific resistance, reduces considerably the life of the alloy at high temperatures. Resistance to oxidation of this ternary alloy, although reasonably high, is by no means equal to that of the 80–20 alloy. The presence of iron oxide in the coating results in slow but certain oxygen penetration, and for that reason the alloy cannot be used continuously at temperatures exceeding 1,000° C. Even at this temperature the element has a somewhat limited service, whereas an 80–20 alloy used at a similar temperature, will give much longer service. Some of the reliable brands of 80–20 nickel-chromium electric resistance heating alloys include Nichrome IV,[3] Brightray,[4] and Pyromic,[5] and the leading electrical, mechanical, and thermal properties of these alloys are given for purposes of reference.

NICHROME IV.

Specific resistance	108 microhms per cub. cm.
Temperature coefficient of resistivity.	Varies with temperature (see Fig. 2).
Melting point	1,390° C.
Specific gravity	8·50.
Tensile strength (annealed rod)	54 tons per sq. in at 20° C.
Coefficient of thermal expansion	0·000013 per ° C., 20°—100° C.

BRIGHTRAY.

Specific resistance	103 microhms per cub. cm.
Temperature coefficient of resistivity.	Varies with temperature.
Melting point	1,375° C.
Specific gravity	8·35.
Tensile strength (annealed rod)	50 tons per sq. in.
Coefficient of thermal expansion	0·0000125 per ° C.

PYROMIC.

Specific resistance	102 microhms per cub. cm.
Temperature coefficient of resistivity.	Varies with temperature (see Fig. 4).
Melting point	1,390° C.
Specific gravity	8.5
Tensile strength (annealed rod)	54 tons per sq. in.
Coefficient of thermal expansion	0·000012 per ° C.

These alloys are manufactured to supply heating elements for electric furnaces and for many other applications where long service is of primary importance, at temperatures between 850° and 1,150° C. It will be appreciated that the higher the temperatures at which the alloys are used the shorter will be their useful life. In the annealed condition they are soft and ductile, and are easily formed into coils, hairpins, or whatever forms the elements are desired to have. As a rule, wire and ribbon is available in the oxidised or bright-finished condition.

The nickel-chromium-iron alloy, which is less costly, is manufactured for applications where a lower temperature is required. Some of the most reliable brands of this ternary alloy include Nichrome,[3] Glowray,[4] and Calomic,[5] and the leading electric, mechanical, and thermal properties of these brands are also given for reference purposes.

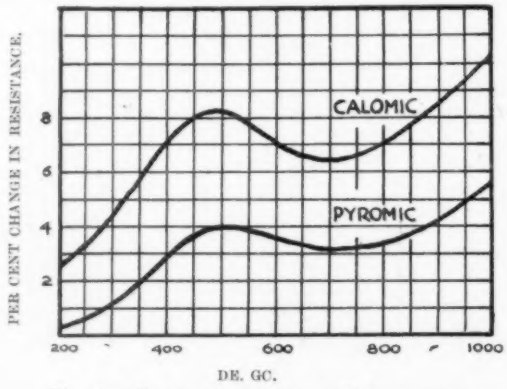


Fig. 4.—Change of resistance with temperature.

NICHROME.

Specific resistance	112 microhms per cub. cm.
Temperature coefficient of resistivity.	Varies with temperature (see Fig. 2).
Melting point	1,350° C.
Specific gravity	8·15.
Tensile strength (annealed rod)	45 tons per sq. in. at 20° C.
Coefficient of linear expansion	0·000014 per ° C., 20°—100° C.

2 Rohn, *Elektrotech. Zeit.*, 1927, 48, 227-317.

3 Manufactured by British Driver Harris Co., Ltd.
4 Manufactured by Henry Wiggin and Co., Ltd.
5 Manufactured by The Telegraph Construction and Maintenance Co., Ltd., and marketed by Wild-Barfield Electric Furnaces, Ltd.

GLOWRAY.

Specific resistance	106 microhms per cub. cm.
Temperature coefficient of resistivity.	Varies.
Melting point	1,400° C.
Specific gravity	8·27.
Tensile strength (annealed rod) ..	45 tons per sq. in.
Coefficient of thermal expansion..	0·0000125 per ° C., 20°—100°C.

CALOMIC.

Specific resistance	104 microhms per cub. cm.
Temperature coefficient of resistivity.	Varies with temperature (see Fig. 4).
Melting point	1,400° C.
Tensile strength.....	50 tons per sq. in.
Coefficient of thermal expansion..	0·000012 per ° C., 20°—100° C.

These alloys may be used up to temperatures of 1,000° C., and the working qualities are similar to the 80–20 alloy, but it must be distinctly understood that the binary alloy, 80% nickel and 20% chromium, is much superior to the nickel-chromium-iron alloy as an electrical resistance material for use at high temperatures.

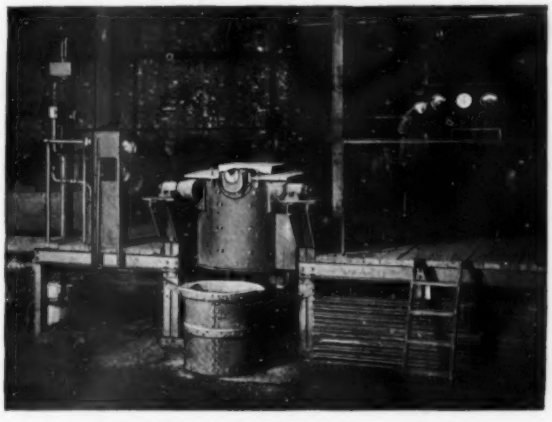
THE WITTON HIGH-FREQUENCY INDUCTION FURNACE.

STEEL experts from various parts of the country assembled recently at Newcastle to witness a demonstration of steel melting by means of the Witton high-frequency induction furnace. This furnace has the advantage that steel and other alloys are melted under conditions which ensure that the product is identical in composition with the arithmetical sum of the materials charged into the furnace. The charge cannot take up sulphur as it does in coke or producer gas-fired furnaces, or carbon as in the electric-arc furnace, while injurious non-metallic oxide or slag inclusions are eliminated. When the metal is molten an automatic stirring effect is produced electrically within the charge; this ensures uniformity of composition throughout each charge.

When melting alloys, such as high-speed steel, the constituent materials of which vary in specific gravity, this continuous automatic mixing is essential if the ingots are to be identical in composition throughout. The high-frequency furnace is essentially a quick-melting unit, and it is particularly suitable for intermittent use.

The economic advantages are of equal interest, as the improved metallurgical conditions and facilities for precise control, which this furnace affords, instead of being accompanied by increased operating costs, are actually obtained at lower cost. Since the heat is produced within the charge itself, the thermal efficiency of the furnace is remarkably high, and the current consumption per unit of output is less than that of the arc furnace. Based upon average rates for electric supply in industrial districts, for instance, steel, at least equal in quality to the best crucible steel, is produced at approximately half the cost of the crucible process. So far as labour is concerned there is little supervision or attention required other than charging and pouring. Labour requirements are therefore reduced to a minimum. The feature of rapid melting has an important economic value, as it renders a furnace of small-unit capacity capable of a comparatively large output. The speed of melting is completely under control, and can, therefore, be adjusted to suit individual requirements.

The path of the magnetic field in this furnace is through thin laminations of special alloy steel, which has a conductivity for magnet flux several thousand times that of an air path. This alloy-steel path is brought to a central position right inside the axis of the inductor coil. The result is that instead of creating a magnetic field vastly weakened by air resistances and uncontrolled as regards its distribution within the crucible, the electro-magnetic system furnishes an intensely strong and centrally situated magnetic field inside the crucible for the more economic melting of the charge. Consequently, the rest of the electrical equipment can be made entirely subservient to the safety of the operators and plant. It is also the presence of this alloy-steel container and core which permits iron and steel to be used throughout to encase the furnace. In addition to the magnetic field being concentrated by it towards the centre of the crucible for more effective work, the stray magnetic fields outside the inductor coil are reduced by it to an imperceptible amount.



A Witton high-frequency induction furnace.

The high-frequency furnace, which is made by The General Electric Co., Ltd., of Magnet House, Kingsway, London, W.C. 2, under Stobie Patents, is of strong and robust construction, highly efficient and economical to run, perfectly safe to operate, and provides an ideal melting unit.

Developments in Rod and Wire Mills

(*Continued from page* 124).

grooves in the vertical and horizontal rolls, the vertical stands were mounted on a plane inclined at 45°, up which it could be moved, as shown in Fig. 6. To permit this movement each stand was fitted with an independent motor, mounted, along with the pinion housing, on a crosshead on top of the stand. To change the rolls this crosshead is raised and swung round out of the way. The horizontal stands have also separate motors, and are placed very close up to the vertical rolls, while giving good accessibility to all parts. The motors of this finishing mill are all of 200 h.p., with speed variation from 0 to 1,700 r.p.m.

The individual drive of the stands of the No. 2 finishing mill, differing from American practice, was adopted owing to the exacting demands of European buyers in regard to close limits of size. It also simplified the employment of the vertical rolls, with the resultant advantage of dispensing with guides.

The finishing speed of 4,530 ft. per min. necessitated absolutely reliable construction of the roll bearings. With the ordinary proportions this gives a journal speed of about 2,760 ft. per min., compared with about 985 to 1,180 ft. per min., with the former open-type mill. Attempts to design plain bearings were abandoned, since it was not possible to secure absolute reliability, especially in regard to the lubrication for the vertical rolls. The design of self-aligning bearing with barrel-shaped rollers, shown in Fig. 7, was therefore adopted.

The swifts are placed about 43 ft. from the finishing stand. Two special swifts, with electrically operated diverting switch, are provided for each strand, the rod being coiled alternately on these. Each pair of swifts is driven by a variable-speed motor of 24·5 h.p.

Some Recent Inventions.

Making Seamless Tubes.

THE usual practice in the manufacture of seamless tubes consists in casting ingots which are allowed to solidify and then soaked in soaking pits. These are subsequently rolled in blooming mills into large square blooms, which after cooling are reheated and rolled on merchant mills into rounds, the size of which being determined by the diameter and wall thickness of the tube to be produced. Many successive mechanical working operations, as well as frequent heating and cooling operations, are involved by this process, and in order to limit these operations and reduce time, labour, and expense in the production of seamless tubes, a method has been developed for making seamless steel tubes direct from molten metal.

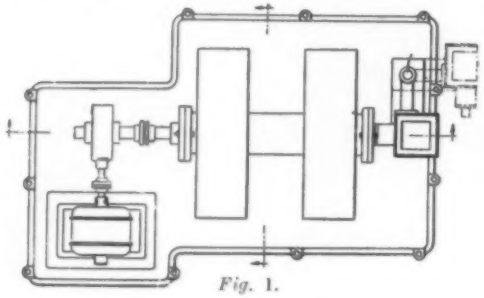


Fig. 1.

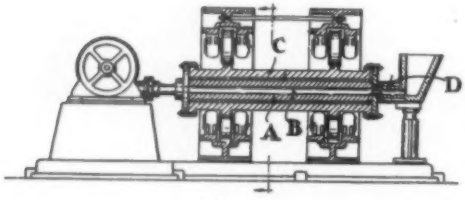


Fig. 2.

The method consists in producing centrifugally a cylindrical piece of metal having a concentric axial hole from the molten metal, and then concentrically displacing the metal round the bore by an expanding plug. In this way the structure of the metal around the bore, resulting from the centrifugal process of casting, has a physical structure uniform with the structure of the metal at or near the periphery of the semi-finished tube. The semi-finished tube is then passed through one or more tube rolling mills for thinning the walls and producing the finished tube of required size.

A plan and sectional elevation of a centrifugal casting machine are shown at Figs. 1 and 2 respectively. In this machine the cylindrical blank A, having a concentric bore B, may be made. The mould C may be rotated by any suitable means. Molten metal which has been refined in an electric or open-hearth furnace and tapped into a ladle, is poured into the spout D at a temperature above 1,430° C. The metal then flows into the mould cavity. Meanwhile, the mould is rotated at a peripheral speed sufficient to cause the molten metal to respond to the action of centrifugal force to form the cylindrical blank.

The spout may be rotated, as shown by dotted lines in Fig. 1, to facilitate the stripping of the blank from its mould. In order to retain its mould heat it is placed in a holding furnace from which it is taken and passed through an expanding mill indicated in Fig. 3. This mill may be a modified form of Mannesmann piercing mill, in which the blank A is rotated and passed longitudinally in the direction of the arrows shown in Fig. 3, over the expanding head indicated at E. The semi-finished tube, produced as a result of this process, is then passed through the usual type of tube rolling mill, shown diagrammatically in Fig. 4, in which the tube is reduced to the required size. The tube thus produced may be reeled and sized to provide hot finished tube, which may be later cold-drawn to make cold-finished tube.

It is claimed that this method of making seamless tubes of steel and other metals directly from molten metals improves and simplifies the procedure by eliminating many unnecessary and harmful operations, in order to attain substantial uniformity, with an improved metal structure of the finished product.

362,207. TIMKEN HOLDING AND DEVELOPMENT CO., Wilmington, U.S.A., patentee; FRANK B. DEHU AND CO., agents, 103, Kingsway, London, W.C. 2. Accepted December 3, 1931.

Effect of Mechanical Treatment on Molecular Structure.

THE magnetic permeability of a ferromagnetic material or alloy is increased by subjecting the material, prior to the final heat-treatment, to a predetermined amount of cold working, so as to reduce the material to the finished size without producing an overworked or underworked condition. It is claimed that an ingot of the material, cast in a chill mould, when reduced at a temperature of about 1,000–1,100° C. by rolling to a thickness between three and four times that of the finished product, and then reduced by cold rolling, without intermediate annealing, the amount of cold rolling being sufficient to produce, on recrystallisation, the octahedral crystal structure, gives maximum permeability. When a very thin product is desired, the cold rolling may be effected in two stages, and an example is given in which certain alloys may be hot rolled to a thickness of 0·06 in., cold rolled to 0·018 in., or 0·02 in., annealed, and finally cold rolled to 0·005 in., and given a heat-treatment at about 1,150° C. When the alloy has received excessive cold working the magnetic permeability may be increased by a more prolonged heat-treatment. Additional elements, such as silicon, in small quantities, may be made to render the crystalline formation more readily attainable, examples of such alloys being (1) iron 16·8%, chromium 1·6%, manganese 0·7%, copper 5·0%, and silicon 0·2%; (2) iron 16.8%, chromium 1.6%, manganese 0.6%, copper 5.0%, and silcon 0.2%; or (3) iron 16·65%, chromium 1·36%, manganese 0·4%, copper 4·9%, and silicon 0·18%, the remainder in each case being nickel. The alloy of example (3) is reduced by cold rolling to a strip 0·015 in. thick, the reduction being about 60%, is then sheared to a width of $\frac{3}{4}$ in., wound into a spiral of 3 in. internal diameter, and 4·9 in. external diameter, and is finally treated in a neutral atmosphere at 1,120° C. for 30 mins., and cooled in an annealing box, withdrawn from the furnace. It is stated that with alloys having a high nickel content, the initial permeability produced is generally considerably greater than that of iron ($\mu = 250$), but with some materials, such as those having a high specific resistance, the initial permeability may be less than that of iron.

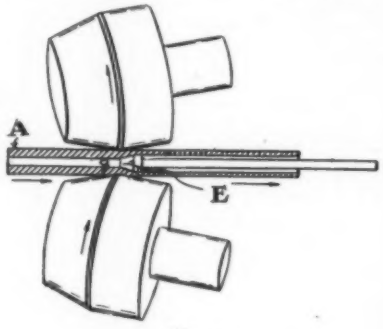


Fig. 3.

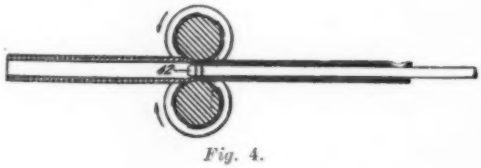


Fig. 4.

366,523. W. S. SMITH, Newton Poppleford, Devon; H. J. GARNETT, Sevenoaks, Kent; and W. F. RANDALL, Ewell, Surrey, patentees.

The Electrical Conductivity of Copper*

By G. Elsner and P. Siebe.

The results of an investigation of the alteration in conductivity with the annealing temperature and also with the degree of cold-working after varying heat-treatments. The curves given in the illustrations are drawn to a scale which emphasises the maximum values.

APART from the well-known influence of the chemical composition on the electrical conductivity of copper,[1] a very important rôle is played by the cold-working and heat-treatment to which the copper is subjected. Cold-working generally results in the reduction of the conductivity by two to three units. According to experiments by Gewecke,[2] the conductivity falls to a minimum at 50% reduction in cross-section; further cold deformation causes a transitory rise, which is followed by a sharp decline. As against this, Bardenheuer and Schmidt[3] have shown that with more than a 50% reduction in cross-section the conductivity gradually increases with the degree of cold-working. They agree with Gewecke that there is a minimum value for the conductivity at 50% reduction, though they make the reservation that this minimum only occurs when the draws are weak. By heat-treating cold-worked copper at low temperatures (stress removal) it is possible to raise the conductivity considerably, without any noticeable decrease in strength occurring. Further increase in temperature causes a decrease in strength, and, to begin with, a considerable increase in the conductivity (up to three units), followed by a rapid fall. According to different investigators, the temperatures at which maximum values for the conductivity are obtained lie between 300° and 500° C.[4]

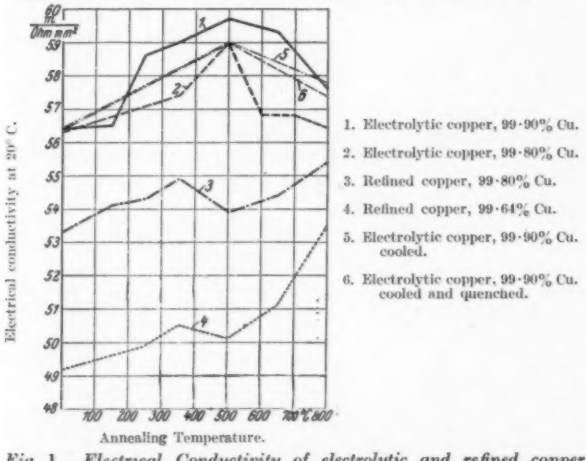

Electrical conductivity at 20° C.
Annealing Temperature.
1. Electrolytic copper, 99·90% Cu.
2. Electrolytic copper, 99·80% Cu.
3. Refined copper, 99·80% Cu.
4. Refined copper, 99·64% Cu.
5. Electrolytic copper, 99·90% Cu. cooled.
6. Electrolytic copper, 99·90% Cu. cooled and quenched.

Fig. 1.—Electrical Conductivity of electrolytic and refined copper. Influence of annealing temperature (curves 1 to 4) and of rate of cooling (curves 5 and 6, Amer. wire bars).

The different effects of cold-working and heat-treatment on the conductivity obtained by different investigators calls for some explanation. Certainly, differences in the chemical composition of the copper wires contributed in no small degree to the differences in the experimental results. Fully to investigate the importance of this fact was beyond the scope of the present work, and it was only taken into consideration to the extent that samples of copper of different degrees of purity were used. The work had for its object the investigation of the alteration in conductivity with the annealing temperature, and also with the degree of cold-working after varying heat-treatments, and the explanation of the differences obtained by previous workers, so far as there was any connection with these.

Production of Samples and Arrangement of Experiments.

Four qualities were prepared for the experiments, as shown in Table I.

In each quality the starting point was hard-drawn wire 3 mm. in diameter. The electrolytic copper wire was produced by the normal factory process, by hot-rolling a wire billet (100 mm²) to 6 mm. diameter wire and cold-drawing to 3 mm. diameter in three draws, without intermediate anneal. For the refined copper wire, strip of about 40 mm.² cross-section was obtained from the sheet-mill and drawn to 3 mm. diameter wire in the same manner as the electrolytic copper. The coils were divided into seven parts, each about 2 to 3 metres long, and of these one length in the unannealed state, and the others after a half-hours, heat-treatment at temperatures between 0° and 800° C.

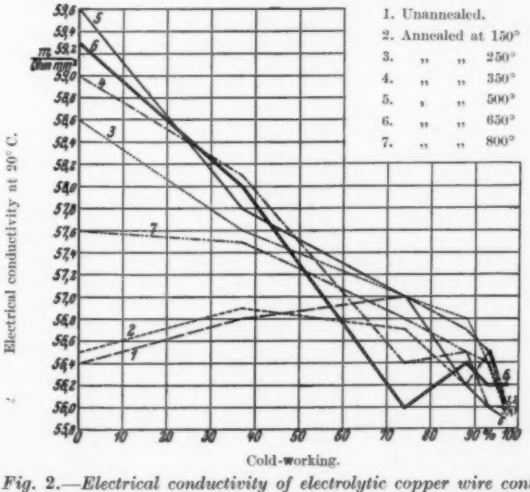


Fig. 2.—Electrical conductivity of electrolytic copper wire containing 99·90% Cu (Amer. wire bars). Influence of cold deformation. The wires were annealed at a diameter of 3 mm.

were tested for conductivity. The several differently annealed wires were further cold-drawn to a diameter of 0·5 mm., corresponding to a cold-working of about 97%. During the drawing process four further samples, of diameters 2·4 mm., 1·5 mm., 1·0 mm., and 0·75 mm., were taken, so that there were available for the conductivity tests six samples having the same thermal treatment, but different degrees of cold-working. Table II. shows the degree of cold-working undergone by the several wires, the cross-sectional areas of which were determined by weighing.

The wires were annealed in an electrically-heated muffle with access of air, and in general were quenched after annealing. In one case (E-copper with 99·90% Cu) one wire was cooled and one quenched after the 500° and the 800° C. anneals, as it was possible that the rate of cooling

* Translated from "Uber die elektr. Leitfahigkeit von Kupfer," *Zeitsch. fur Metallunde*, December, 1930, by I. Boodson.

1 C.f., also "Kupfer," VDI publication, p. 19, *et seq.*

2 Thesis for Doctorate, T. H. Darmstadt, 1909.

3 Comm. from the Kaiser Wilhelm-Inst.f.Eisenforschung, vol. 10 (1928), p. 193.

4 For complete bibliography, see Bardenheuer and Schmidt, *loc. cit.*

might exert a certain influence on the conductivity. Thomson's double bridge was used for determining the conductivities; the room temperature was 20° C. throughout.

TABLE I.

MATERIALS USED.

Material.	Charge.	Analysis.							Electrical Conductivity of 3 mm. Wire, Hard-drawn. $\frac{m}{Ohm.mm^2}$
		Cu. %	Pb. %	Ni. %	As. %	Sn. %	Sb. %	O. %	
Electrolytic copper (Amer. wire bars).*	—	99·90	—	—	—	—	—	0·05	56·4
Electrolytic copper (reverberatory furnace).	O'd electrolytic.	99·80	0·05	0·02	0·01	0·01	0·01	0·06	56·3
Refined copper (reverberatory furnace).	Crude copper, old electrolytic & scrap	99·80	—	0·09	0·015	0·014	0·024	0·08	53·3
Refined copper (reverberatory furnace).	Crude copper, old Electrolytic & scrap	99·64	—	0·17	0·01	0·04	0·04	0·075	49·2

* Special value was attached to the high conductivity.

Each of the four qualities of copper provided one wire in the hard-drawn condition, and six which had been annealed at temperatures between 100° and 800° C. for the determination of the dependence of the conductivity on the heat-treatment, and each of these wires provided six samples after cold-working, the amounts varying from about 30 to 97%, for determination of the conductivity after cold-working.

TABLE II.

COLD DRAWING OF ROLLED WIRE (6 MM. DIAM.).

Cold Drawn. From	To	Number of Draws.	Cold Work, %
6·0 mm. dia.	3·0 mm. dia.	3	75
*3·0 "	2·4 "	1	38
2·4 "	1·5 "	3	75
1·5 "	1·0 "	3	90
1·0 "	0·75 "	3	94
0·75 "	0·5 "	4	97·5

* With an intermediate anneal at 3 mm. dia.

Influence of Annealing Temperature on the Conductivity of Hard-drawn Copper Wire.

(*a*) *Electrolytic Copper containing* 99·90% *Cu* (Fig. 1, Curve 1).—The conductivity of the wire rises with the annealing temperature from 56·4 in the hard-drawn state to a maximum of 59·7 $\frac{m}{Ohm.mm^2}$ at 500°, after which it falls as the temperature rises, slowly at first, then fairly quickly to 57·6 at 800° C. For conductivities not less than 59 $\frac{m}{Ohm.mm^2}$ the temperature range extends from 350° to 650° C.

The rate of cooling had practically no influence on the conductivity of the annealed wire in the case of the samples tested (Fig. 1, Curves 5 and 6).

(*b*) *Electrolytic Copper containing* 99·80% *Cu* (Fig. 1, Curve 2).—The influence of the annealing temperature again shows itself in an increase in the conductivity from 56·3 in the hard-drawn state to 59·0 $\frac{m}{Ohm.mm^2}$ when annealed at 500° C. Above this temperature the conductivity falls, quickly at first, then more slowly, till at 800° it is 56·4. The temperature range for high conductivity is narrower than in the case of the first electrolytic copper investigated, the slope of the curve on either side of 500° C. being very steep. Owing to the lower copper content, the conductivity is in general lower than that of the electrolytic copper containing 99·90% Cu.

(*c*) *Refined Copper containing* 99·80% *Cu* (Fig. 1, Curve 3).—As in the case of electrolytic copper, the conductivity rises with the annealing temperature from 53·3 in the hard-drawn state to a maximum of 54·9 $\frac{m}{Ohm.mm^2}$, which is, however, attained at 350° C. Above this temperature it falls slightly, but at 500° again begins to increase, unlike electrolytic copper, and rises to its maximum value of 55·4 $\frac{m}{Ohm.mm^2}$ at 800° C.

(*d*) *Refined Copper containing* 99·64% *Cu* (Fig. 1, Curve 4).—The annealing treatment influences the conductivity of this quality in the same manner as that of the other refined copper. Up to 350° the value rises (from 49·2 to 50·5), and between this and 500° falls again to a slight extent. Above 500°, however, the increase in the conductivity is much greater than with the refined copper, containing 99·80% Cu, being from 50·1 at 500° to 53·5 $\frac{m}{Ohm.mm^2}$ at 800°.

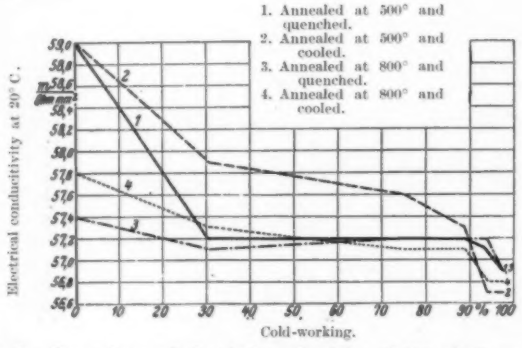


Fig. 3.—Dependence of electrical conductivity of electrolytic copper wire containing 99·90% Cu (Amer. wire bars) on cold-working and rate of cooling. The wires were annealed at a diameter of 3 mm.

It is thus seen that the conductivity of hard-drawn copper wire (electrolytic and refined) increases, in the temperature ranges 0° to 500°, and 0° to 350° respectively, with increasing annealing temperature. At temperatures lying between 350° and 500°, according to the purity of the copper, the conductivity reaches a maximum. In the present series of experiments, the increases between 0° and 350°, or 500°, were :—

Electrolytic copper, containing 99·90% Cu	3·3 units
" " 99·80% Cu	2·7 "
Refined copper, containing 99·80% Cu	1·6 "
" " 99·64% Cu	1·3 "

As the degree of purity falls, the height of this first maximum value is reduced.

In the temperature range between 500° and 800° the conductivity of both qualities of electrolytic copper falls to approximately that of the hard-drawn wire; that of the refined copper, on the contrary, rises again, in part very sharply.

Influence of Cold-working.

Consider the conductivity of copper wire after heat-treatment at different temperatures :—

(*a*) *Electrolytic Copper containing* 99·90% *Cu* (Figs. 2 and 3).—The higher the initial value, the greater is the reduction in the conductivity on cold-working—*i.e.*, it is greatest in those wires which were annealed in the temperature range 350° to 650°. Conversely, those wires having the lower conductivities originally show a slight increase at first,* so that even with 30% cold-working there is a marked assimilation of the differences in conductivity, due to the different heat-treatments. With further cold-working, these differences are more and more obliterated, until in the wires cold-drawn to the extent of 90% they are practically no longer present.

* When considering curves 1 and 2 (unannealed wire and wire "tempered" at 150°) it must be borne in mind that these wires had been cold-worked (to the extent of 75% in the unannealed wire) to a diameter of 3 mm. prior to the experiment: the upward slope of the first portion of these curves is, therefore, in agreement with the previously mentioned observation of Bardenheuer and Schmidt to the effect that, when the cold work exceeds 50%, the conductivity again increases.

The rate of cooling, which, as already noted, has no marked influence on the conductivity of the annealed wires, so far affects the cold-worked material that, in general, the values for the slowly-cooled wires are at first slightly higher than those for the quenched ; with heavier cold-working (90%) these slight differences are equalised, just as are those due to different annealing temperatures (Fig. 3).

(*b*) *Electrolytic Copper containing* 99·80% *Cu* (Fig. 4).—With 30% cold work the conductivity of the wire annealed at 500°, and having originally the highest values, was again most heavily reduced, the others undergoing only slight reductions and even in some cases a considerable increase. In contrast to the 99·9% electrolytic copper, with which there is a continuous fall in the slope of the curves, there is a definite retardation to be noticed in the reduction in the conductivity between 30% and 75% cold-working. 90% cold-working still further reduces the effect of the different heat-treatments, but the assimilation of the values is not so marked as in the case of the 99·9% electrolytic copper. The wire annealed at 800° behaves differently from all the others ; the conductivity rises up to a cold-working of 75%, and then falls again at about 97·5%. No explanation of the peculiar behaviour of this wire can be offered at the moment.

(*c*) *Refined Copper containing* 99·80% *Cu* (Fig. 5).—Here 30% cold-working causes the heaviest reduction in conductivity in the wires annealed at 350° and 800°, which have originally the highest values. The retardation in the fall of the conductivity curves beyond 30% cold-working, already noticed in one case in the electrolytic copper, is much more marked here. The conductivity remains practically constant from 30 to 90% cold-working. Above 90% there is again a rapid drop in all the values. The differences in the conductivities of the various wires, due to the different heat-treatments, are very largely removed by the cold-working in this case also, though not to the same extent as in the electrolytic copper.

(*d*) *Refined Copper containing* 99·64% *Cu* (Fig. 6).—In general, the conductivity is but slightly lowered by cold-working, the curves being approximately horizontal between 0 and 95%. Not till the reduction in cross-sectional area is 97·5% do the values fall at all sharply. The differences in conductivity induced by the different heat-treatments still persist after a cold-working of 97·5%.

The experiments show that, as a general thing, cold-drawing lowers the conductivity of copper, the effect being the more marked the higher the initial value. As the degree of purity of the copper falls, so the influence of cold-working decreases.

With electrolytic copper containing 99·80% Cu, and still more with the refined coppers, a definite retardation of the decrease in conductivity occurs at medium degrees of cold-working (above 30%), the course of the curves being practically horizontal. This phenomenon does not occur with electrolytic copper containing 99·90% Cu.

The differences in conductivity due to different heat-treatments are almost entirely obliterated in the electrolytic coppers and the better quality refined copper by heavy cold-working ; the differences disappear the more quickly—*i.e.*, by smaller amounts of cold deformation, the purer the copper. In refined copper of low purity the differences persist.

The rate of cooling after the heat-treatment has, according to these results, practically no influence on the conductivity of the unworked or of the cold-deformed electrolytic copper.

Consideration of Experimental Results.

The annealing experiments show that heat-treatment of hard-drawn copper wires at medium temperatures results in the attainment of maximum values for the conductivities ; the range for maximum conductivity becomes smaller as the degree of purity falls. At temperatures above 500° the conductivity of electrolytic copper falls, whereas that of refined copper undergoes a further, and in some cases a considerable, rise.

As already mentioned, previous work has frequently dealt with the alteration in conductivity of electrolytic copper with the annealing temperature, and in some cases it has been assumed that the falling-off at high temperatures (above 500°) was due to the coarse recrystallisation induced,

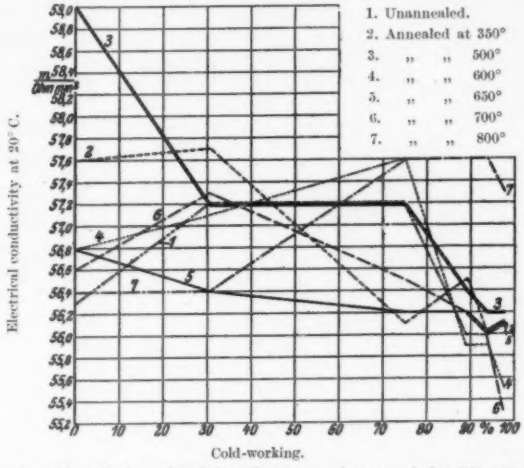


Fig. 4.—Electrical conductivity of copper wire containing 99·80% *Cu (reverberatory furnace electrolytic copper). Influence of cold-working. The wires were annealed at a diameter of* 3 *mm.*

whilst in others the tendency of electrolytic copper to absorb gases has been suggested as the cause ; the consequent sponginess of the structure causes a deterioration in the mechanical and electrical properties. If the four conductivity curves (Fig. 1) obtained in the present series of experiments be considered in this connection, however, it will be seen that the above explanations cannot apply to refined copper, which attains its maximum value at a lower temperature than does electrolytic copper, and in fact in a temperature range in which there is no tendency to coarse crystallisation or to absorption of gas. If the determining factor were merely the influence of temperature, the fall in conductivity might be expected to occur at higher temperatures in refined than in electrolytic copper, owing to the lesser temperature sensitivity of the more impure qualities of copper. One cannot rule out the

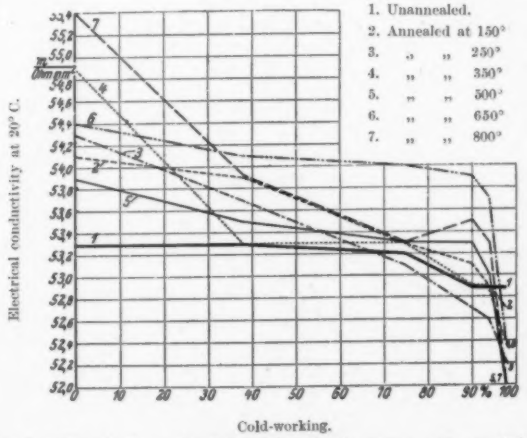


Fig. 5.—Electrical conductivity of refined copper wire containing 99·80% *Cu (reverberatory furnace refined copper). Influence of cold-working. The wires were annealed at a diameter of* 3 *mm.*

possibility of the fall subsequent to the attainment of the maximum value being due to peculiarities in the structure of the copper or to properties connected therewith, which in the case of electrolytic copper would naturally have a considerable effect, owing to the simultaneous coarsening of the structure and absorption of gas. The rise in the conductivity of the refined coppers investigated at higher

temperatures may be connected with peculiarities in chemical composition, which suggest separation effects. Whether this type of influence is present must be left to future experiments to decide.

So far as the general course of the conductivity curves of electrolytic copper is concerned, the results obtained are the same as those of previous investigators, but as regards the annealing temperature for maximum conductivity and the magnitude of the decrease in the latter the data of previous workers show not inconsiderable deviations. Bardenheuer and Schmidt,[5] in whose experiments the period of anneal was 1 hour, found the temperature range for maximum conductivity to extend from 350° to 500° C. Gewecke[6] obtained a maximum value after 2 mins. at 350°, Credner[7] a similar result after 3 mins. at 450°. After annealing at 800°, Credner and Gewecke found that the conductivity had fallen to that of the hard-drawn wire, a result in agreement with the results of the present experiments, whereas Bardenheuer and Schmidt obtained values 8 to 10 units lower than those of the original material. The variability of these experimental results, in particular the marked fall in Bardenheuer's curves above 500°, must

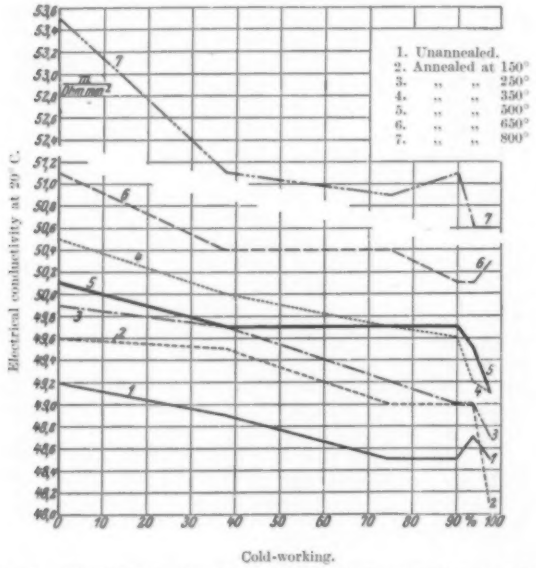


Fig. 6.—Electrical conductivity of refined copper wire containing 99·64% copper (reverberatory furnace refined copper). Influence of cold-working. The wires were annealed at a diameter of 3 mm.

surely be connected to no inconsiderable degree with the different annealing periods adopted by the different investigators in their experiments. How far the connection between the position of the maximum value and the degree of purity of the copper observed in the present work serves to explain the above-mentioned contradictions must be left undecided for the present; this factor is undoubtedly of considerable importance.

In general, cold-working brings a reduction in the electrical conductivity; the percentage decrease is the greater the higher the conductivity before the deformation and the purer the copper. With electrolytic copper, especially if the conductivity in the unworked condition be low, weak and medium cold deformations cause the values to rise. The increase in conductivity when the cold deformation exceeds 75%, which was observed by Bardenheuer and Schmidt, was also found to occur in the present experiments, though only in isolated cases.

The observation that the differences in conductivity of electrolytic and of high-quality refined copper induced by different heat-treatments can be almost completely evened up by sufficiently heavy cold-working is of great importance. The irregular behaviour of refined copper of low purity, in which the influence of the previous heat-treatment is still evident, even after a cold deformation of 97%, is understandable if the course of the curves is considered in relation to the purity of the four qualities of copper investigated. The purer the copper, the weaker the cold deformation, which suffices to even up the original differences in conductivity. It may therefore be concluded that as soon as a sufficiently heavy cold deformation takes place the several conductivity curves for refined copper will converge in the same way as do those for electrolytic copper. The influence of chemical composition is apparently such that the considerably greater separation of impurities in the refined copper having the lowest Cu content disturbs the equalising action of the cold-working.*

In practice, the previous heat-treatment is consequently of no particular importance to the electrical conductivity of electrolytic copper wires, which are used in the hard-drawn condition. As, however, for reasons already mentioned, the deterioration in the electrical properties at high temperatures is accompanied by a reduction in the mechanical properties, it is advisable not to exceed an annealing temperature of 500° C. Likewise, for wires required in the soft state, an annealing temperature not above 500° is advisable.

5 *Loc. cit.* 6 *Loc. cit.* 7 *Z. Phys. Chem*, vol. 82 (1913), p. 457.

Summary.

The influence of different heat and subsequent mechanical treatment on the electrical conductivity of four qualities of copper of different degrees of purity was investigated, and it was established that heat-treatment of electrolytic and refined copper over a range of medium temperatures gave maximum values for the conductivity; this range becomes narrower, and is displaced to lower temperatures, as the degree of purity of the copper falls. The decrease in the conductivity subsequent to the attainment of the maximum value is probably connected with peculiarities in the structure of the copper. At higher annealing temperatures the conductivity of electrolytic copper decreases, whereas that of refined copper increases, in part, considerably.

As a general thing, cold-working lowers the electrical conductivity of copper; differences in conductivity due to preceding heat-treatment are more or less completely obliterated, according to the degree of purity of the copper by heavy cold-working. This equalising action is retarded in refined copper of low copper content, owing apparently to separation effects.

Finally, an attempt has been made to explain, on the basis of the experimental results, the contradictory figures for the position of the maximum value, and for the magnitude of the decrease found in the literature.

The Influence of Nickel in Resisting Embrittlement in Low-Carbon Steels.

Studies recently made on nine steels are referred to by H. T. French and C. M. Schwitter,† which illustrate the effects of different nickel contents upon ageing and recrystallisation phenomena. Normalised bars from each of the steels were stretched 5% over a gauge length of 8 in. at room temperatures, reheated for one hour at selected temperatures, then notched as quickly as possible after cooling, and tested. The results show that four steels with about 1·50% or more of nickel were free from ageing embrittlement, whereas five of the steels without nickel showed ageing embrittlement involving losses in Izod impact values ranging from 30 to 70%. Briefly, the results of the investigation indicate that an increase in nickel content in low-carbon steels reduces ageing embrittlement, reduces the grain size which can develop on recrystallisation, and raises the temperature at which strain markings of maximum intensity are observed in strain-etch tests. The authors state that appreciable benefits are obtained with additions of about 2% of nickel, but the improvements increase with increase in the nickel content up to about 5% (the limit investigated.)

* The influence of the impurities in the refined copper with the lowest copper content may be represented as resulting in the formation of a number of different alloys according to the annealing temperature, in which case a convergence of the various curves would be very unlikely to occur even after the heaviest cold deformation.

† Nickel Steels Resist Embrittlement, *The Iron Age*, vol. 130, No. 2, pp. 51-53.

Refractory Materials for Air-Heating Furnaces

By Alfred B. Searle, *Consultant.*

Many refractory materials fail to give satisfactory service because the conditions under which they are used are not understood by manufacturers, and in this article some essential factors are discussed with respect to refractories for air-heating furnaces.

THE conditions to which refractory materials are subjected in an air-heating furnace are not usually severe so far as simple refractoriness or resistance to heat is concerned, but many materials fail to give satisfactory service because the conditions of use are not understood by the manufacturers.

In the first place, the purpose of an air-heating furnace is, as its name implies, to heat the air used in a blast-furnace or for other purposes. If the supply of hot air is to be constant and a recuperative type of furnace is used to heat it, the condition in which the refractory materials are to be maintained is fairly uniform, and no difficulty should be experienced in obtaining suitable bricks or pipes from any reputable maker. If, on the contrary, the hot-air stove is not in regular use, the frequent heating and cooling of the refractory materials will tend to bring about their destruction unless they are specially designed to withstand such conditions. Even then, the durability of the refractory materials (measured in hours of actual use) will be much less than if they could be maintained day and night at a constant temperature.

Regenerators and Recuperators.

When air at a very high temperature is required, a recuperative heating device is usually impracticable, because no material is available which will transmit heat at a very high temperature for an indefinitely long time; the metals and alloys available are soon oxidised and spoiled when the air has to be heated to temperatures of 1,000° C. or above, and if refractory materials are used the heat-conductivity of most of them is so low that a high temperature is not attained by the air. Under such circumstances, instead of a recuperator, a regenerative type of heater is used in which flames and hot gases are first passed through the appliance, and when the brickwork or other material is sufficiently hot, the gases are shut off and the air to be heated is admitted. By this means, air of any desired temperature is obtainable, and if two or more regenerators are in use the supply of hot air is practically constant, as each regenerator is used and reheated in turn. A serious disadvantage of all regenerators is that the temperature of the heated air is very high at first, but rapidly falls, so that instead of a supply of air at a constant temperature a series of supplies of gradually cooling air is obtained. This appears to be unavoidable where the temperature required is greater than a recuperator can supply.

This distinction between the two types of air-heating furnace is very important when selecting refractory materials, for those suitable for a recuperator are often quite unsuitable for a regenerator and vice versa.

Recuperators.

For air at a temperature not exceeding 800° C., or in some cases 1,000° C., the tubes in a recuperator may be made of metal. Below a red heat, iron tubes are usually satisfactory, and in a well-designed furnace they can be easily and cheaply renewed. For higher temperatures some of the newer heat-resisting alloys may be used, though they are expensive, and there is still some uncertainty as to their durability.

Metals have the great advantage over other materials of having a high thermal conductivity, so that there is little difference between the temperature of the heated air and that of the gases used to heat it. With most refractory materials, on the contrary, the heat-conductivity is so low that there is always a large difference in temperature between the hot air and the heating gases. If the furnace is in constant use, this difference is of small importance, as the counter-current principle of heating can be used to prevent much waste of heat. With intermittent use, however, the loss of heat is very great.

The only refractory materials with a relatively high heat-conductivity are the carbides, the best known of which is carborundum (SiC). This is a highly refractory material, though it tends to decompose on prolonged exposure to hot air. If, however, it is heated during manufacture to such a temperature and under such conditions that a superficial film of fused silica is formed, the carborundum will remain in satisfactory use for a very long time. Its chief disadvantage is its high initial cost, but when its durability and great heat-conductivity are considered it will be found to be cheaper than fireclay in a recuperator.

The firebricks, hollow blocks, or pipes used in air-heating furnaces of the recuperator type are usually made of fireclay to which a variable proportion of grog (calcined fireclay) has been added. Their conductivity is much less than that of carborundum and other carbides of metals, but if the walls are not too thick, good results are obtained.

Fireclay pipes, hollow blocks and bricks used in recuperators should have a moderately close texture or the heating gases will pass into the air passages and spoil the air. Too close a texture, on the contrary, will make the materials very sensitive to changes in temperature, and so will reduce the durability.

The bricks or pipes should have ample resistance to the corrosive action of the gases and flue-dust in use. This is not easy to secure, but is very important. It is usually associated with a large proportion of alumina and a close texture. The alumina should be in the form of mullite, and not in the free state; in other words, it should be derived from clay and not from added alumina.

There should also be ample resistance to the abrasive action of dust and ash passing through the recuperator; this is best ensured by using hard-fired bricks of a close texture. Soft or under-fired bricks are almost useless for this class of work.

That the refractory materials used in recuperators should have ample mechanical strength to resist any crushing action to which they are likely to be exposed, and that they should be sufficiently refractory, is so obvious that a mere mention of these properties should suffice. Unfortunately, many users do not understand that the term "refractoriness" relates only to the temperature to which material can be heated in a clean and dustless oxidising atmosphere; under any other conditions the material will be less resistant and may fail, though such failure is not due to low refractoriness, but to some other factor, such as chemical action

with the heating gases. In this connection it is important to note that the heating gases must be free from carbon monoxide, because this gas is decomposed in contact with hot fireclay, and the free carbon liberated chokes the pores and soon blocks any passages, as well as tending to disintegrate the refractory material. If an ample supply of air is admitted to the heating gases whilst they are at their highest temperature, this serious defect will not occur.

The various parts of recuperators require replacement at different times, so that the coefficient of expansion should be as low as possible or serious disintegration may occur. For this reason, the refractory articles should have been well burned at a much higher temperature than they are likely to attain when in use. It is also desirable to obtain them from one firm, as materials from different sources may act detrimentally on one another.

Regenerators.

In regenerators, the brickwork or other material is heated strongly by hot gases and flames, and then, by moving a valve or damper, a current of air is drawn through the regenerator and is heated in its passage. The rapid changes from hot gases to cold air and vice versa, and the high temperatures attained, produce conditions which are very severe on the firebricks used, so that it is necessary to select them with great care or they will break down prematurely. The bricks should have been hard burned, and should be free from obvious signs of fusion. For prolonged use, bricks which have been fired at a temperature below 1,400° C. should usually be rejected or employed in the cooler parts of the regenerator.

The properties to be possessed by firebricks used in regenerators should be the same as those for recuperators, but as the conditions in the latter are more severe, a higher refractoriness and a greater resistance to corrosion and abrasion are usually needed. In addition, the bricks used in a regenerator are subjected to such sudden and oft-repeated changes in temperature that they must not be unduly sensitive in this respect.

When a regenerator is rather small for the volume of air passed through it, the latter tends to carry a large amount of dust and coal-ash in suspension. This dust is usually of a basic nature, and readily combines with the silica or fireclay of which most regenerators are constructed, and it is particularly active in destroying porous bricks. Sometimes the dust is rich in metallic oxides carried from the furnace, and is then a particularly active corrodant.

The most obvious means of preventing serious corrosion is to use basic bricks in the part of the regenerator most likely to be affected, but no basic bricks capable of withstanding repeated and sudden changes in temperature are known. It is possible that bricks made of electrically fused magnesia would be satisfactory, but they do not appear to have been used, unless their use is kept secret.

When the amount of dust is small, or it is not highly corrosive, silica bricks may be used instead of fireclay bricks, though the sensitiveness of silica bricks to sudden changes in temperature is objectionable. On the other hand, silica bricks do not decompose carbon monoxide in the heating gases, and therefore regenerators built of silica bricks do not choke so readily as those built of fireclay bricks. The advantages of silica and fireclay bricks are sometimes combined by filling the upper half with silica bricks and the lower half with fireclay bricks—the former being used where the latter would spall as a result of exposure to sudden changes in temperature.

In many regenerators a much larger proportion of silica bricks could be used with advantage, as they have a higher thermal conductivity than fireclay bricks and in this respect are more efficient. They must be protected from sudden changes in temperature by a few courses of fireclay bricks, but this can easily be arranged.

Most silica bricks are composed of particles having coarser grains than those in fireclay bricks, so that they are less readily attacked by some abrasive and corrosive dusts, and this is a further advantage. When the conditions are very severe, however, the wear and tear on fireclay bricks is usually less than on silica bricks. This paradox is explained by a consideration of the effect of the size of the particles on corrosive and abrasive agents.

A hard, coarse particle may be more resistant than a smaller particle, but when the large particle has been destroyed, the space, and therefore the surface available for further attack, is larger than with a fine-grained material, so that under severe conditions silica bricks are often preferable.

Some users have found that porous bricks absorb fused dust and other material, and so do not crack as readily as denser bricks. In most generators, however, bricks of low porosity are found to be more durable, especially if the regenerators are cleaned systematically.

Structural Details.

On considering the various parts of a recuperator or regenerator, it will be realised that all should not be constructed of the same materials. For the hottest parts a material of ample refractoriness is needed; for the parts where the greatest corrosion or abrasion occurs, bricks capable of resisting these conditions are required, just as for the parts where the changes in temperature are the most violent, fireclay bricks are preferable to those made of silica.

A careful classification of the requirements of the various parts of a recuperator or regenerator and the use of bricks in each part of a nature specially suitable to it, will add considerably to the durability of the structure and need not increase the expense. In some cases a small saving in cost is effected.

Subject to variations which are called for by local conditions, the following kinds of bricks are desirable in a regenerator:—

(i.) For the foundation walls, silica bricks of uniform size, laid with the thinnest possible joints, are advantageous as they do not shrink under a continuously applied load as do fireclay bricks.

(ii.) For the sidewalls, close-grained fireclay bricks—preferably with ample grog in their composition—should be used. The lower part of the side-walls may, with advantage, be built of chromite or magnesia bricks, as these offer a great resistance to the slag, but great care in selection is necessary or bricks will be used which spall and crack.

(iii.) The roofs may be built of fireclay bricks or silica bricks, the former being preferable, as they can better withstand the sudden changes in temperature.

(iv.) The checker-work or filling should be mainly of fireclay bricks, but an enterprising firm willing to take the risks incidental to improvements will find it desirable to employ as many silica bricks as can be used without undue spalling, and to use firebricks as a means of protecting the silica bricks from sudden changes in temperature. In some regenerators for 60% of the filling silica bricks can be used, and a greater air-heating capacity is thereby secured.

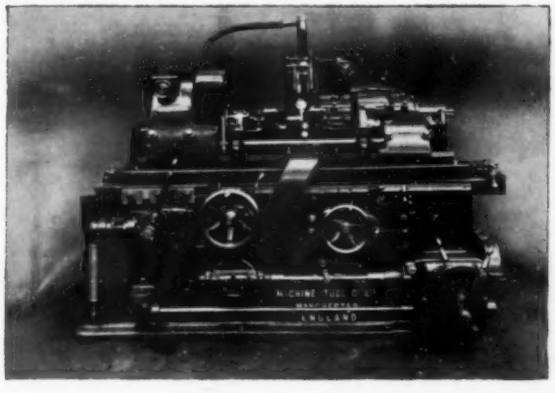
If the regenerator is a very small one, the use of carborundum bricks for the checker-work is well worth consideration, but the cost, in a large regenerator, would probably be prohibitive.

(v.) The flues connecting the regenerator with the furnace should be lined with fireclay bricks, but these may be backed by silica bricks, if desired. A lining of silica bricks is much too sensitive to sudden changes in temperature to be satisfactory. A high refractoriness is not usually necessary for flue-linings, but it would be foolish to use bricks of poor quality. The main flue, through which the hottest gases are passed, should be lined with refractory fireclay bricks or silica bricks, as it is exposed to the highest temperatures.

Recent Developments in Tools and Equipment

MACHINES for GRINDING LIGHT-CAR CRANKSHAFTS.

TWO machines have been recently introduced by the Churchill Machine Tool Co., Ltd., which are essentially manufacturing machines, since each is designed and constructed to perform a single operation. They have been introduced for grinding pins and journals respectively of light-car crankshafts. The machines differ in equipment for carrying the shaft, and that used for grinding pins has a greater swing capacity. Pins and journals can be ground by the straight in-feed or plunge-cut method—that is, using a wheel which, when it is new, has the same width as the pin or journal, but these machines are also fitted with a device on the spacing mechanism which allows a limited table movement for the purpose of compensating for wear on the sides of the grinding wheel.



Machine designed for grinding crankshaft pins.

It is common practice to use double-end drive on machines for grinding crankshafts. This drive usually takes the form of a synchronised mechanism which rotates the work-holding fixtures at either end of the shaft in unison, but with machines of this size the single-end drive is capable of much more consistent and accurate results, and is more simple in construction.

For pin grinding, the crankshaft is supported in cradles or throw blocks which have offset clamps for securing the two end journals, so that the crankpins may be brought into line with the axis of the workhead and tailstock, The throw blocks are designed to be maintained in strict alignment under all conditions, and as balancing of the shaft is carried out at the workhead end only, the crankshaft runs as truly as a plain shaft between dead centres and presents no greater difficulty in grinding. Faulty alignment of the throw blocks is entirely obviated by the special arrangement of widely spaced ball bearings, on which they rotate. The amount of offset of the cradles or throw blocks is fixed on these machines, as it is seldom under manufacturing conditions that one machine is called upon to operate on more than one size of shaft.

A positioning device, simultaneously locking both throw blocks, definitely ensures accurate angular relationship of the throw blocks when the shaft is placed in position.

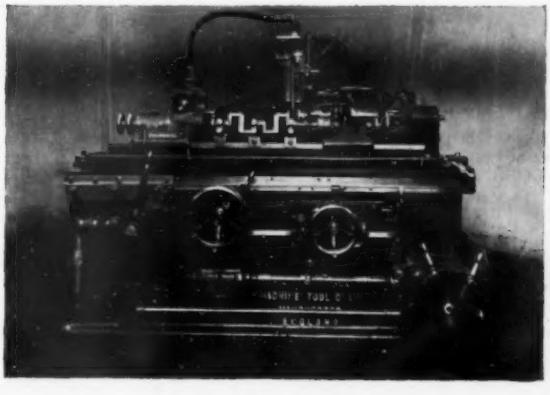
A plunger communicates the drive to the throw block at the workhead end. Upon withdrawal of the plunger, the whole "set-up" can be freely rotated for balancing, which, as mentioned, is confined to the left-hand throw block, the right-hand throw block being merely a freely rotating support to the outer end of the crankshaft. Multiple texropes provide a smooth flexible drive to the drive-plate at the workhead end.

On the crankpin grinding machine the single crankpin steady is interconnected with the wheel-head, so that the two move away from the work simultaneously, thus allowing the shaft to be immediately traversed to bring the next pin to the grinding position. Mounted on the side of the steady is an indicating sizing gauge by which the operator may observe the size of the work at any time. One lever controls the rotation of the work, the traverse of the table (when used), the wheel-head withdrawal, indirectly the steady withdrawal, and the water supply. This one lever control is an important feature, and results in saving time in the operation of the machine.

On the completion of the grinding of a pin, the movement of one lever simultaneously stops the rotation of the work, runs back the grinding-wheel and the steady, stops the table traversing, if traverse is being used, and cuts off the water supply, so that all is ready for the table to be traversed along to present the next pin for grinding.

The longitudinal positioning of the table is by a positive plunger device which definitely ensures accurate distance between pins or journals.

A spacing-bar notched at intervals, corresponding to the spacing of the pins or journals, is secured to the table and into the notches, and registers a plungerfixed relative to the body. The spacing-bar is positioned on the table in correct relation to the facing on the first web. In the case of the pin machine, this facing butts against the facing on the throw-block clamp, whilst in the case of the journal machine a drop latch on one of the steadies can be lowered to make contact with the facing. When the crankshaft is placed in either machine, it must be seen that the facing definitely locates.



A single-operation machine for grinding crankshaft journals.

The aforementioned plunger is carried in the member, which can slide on a dovetail slide attached to the bed, but it is held longitudinally by lock-nuts clamped against a bracket fixed to the bed. If the lock-nuts are slackened off, so as to allow clearance between them and the bracket, the table can be traversed an amount equal to the space, and in this way it is possible to accurately compensate for wear on the sides of the grinding-wheel.

The grinding-wheel head is worthy of note, for the design embodies several features which ensure trouble-free and steady running of the grinding-wheel spindle. The latter is of Nitralloy steel, and runs in widely-spaced finger adjustable bronze bearings, which are lubricated by a flow of filtered oil delivered by a pump running submerged in a large-capacity oil sump. The whole of the wheel head is enclosed; the box formation design which is employed is claimed to be the only one that gives entirely vibration-free

running of the grinding-wheel. This is a quality which is essential for accurate work of high-quality finish.

The grinding-wheel is carried in a balancing-type wheel collet, which is secured to the flanged end of the wheel spindle. The rotation speeds of the work are controlled through a four-speed gearbox. This same gearbox provides four speeds of table travers, but the two sets of speeds are entirely independent of one another, so that any combination may be obtained.

The Churchill roller feed employed on these machines provides a range of feed which can be varied infinitely without the steps inseparable from all ratchet-type mechanisms. It also embodies a sizing device which will operate for either plunge cut or traverse grinding. Another advantage is that the trip for this sizing device does not abruptly disengage the feed, but causes it to diminish at a uniform rate until it eventually dies out. This feature enables a much heavier ratio of cutting to be used than with any other type of mechanism, and at the same time ensures an unusually high quality of finish.

All motions are driven from the main-drive shaft situated at the rear of the machine, and the drive to the shaft can be either by motor or direct by belt from the line-shaft. In the latter case fast and loose pulleys with belt-shifting gear are fitted. Idle time in moving the grinding-wheel when passing from one grinding position to another is minimised by a hydraulic withdrawal mechanism, a noteworthy feature of which is that the setting up of micrometer feed is not disturbed by the hydraulic motion. The control of this hydraulic mechanism is included in the one lever control.

The more important dimensions of the two machines are as follows :—

Crankshaft Pin-grinding Machine—
Maximum swing over table, 14½ in.
Two sizes of machines are built, one accommodating crankshafts 28 in. long, and the other 42 in. long.
Diameter of grinding wheel, 30 in.
Width of grinding wheel, to suit crankshaft.
Number of wheel speeds, 2.
Number of work speeds, 4.
Number of table speeds, 4.
Diameter of grinding-wheel spindle, 4 in.
H.p. required for drive, 20.

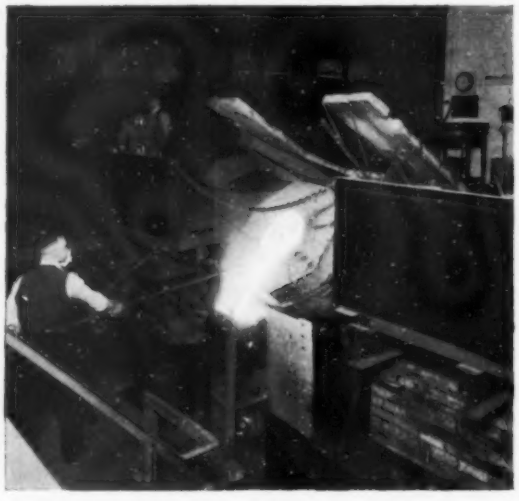
The swing over the table on the journal grinding machine is 10½ in., and owing to the fact that throw blocks are not employed on this type of machine, a greater length can be accommodated. The two sizes of machines accommodate 36 in. and 50 in. between centres respectively.

ONE-TON HIGH-FREQUENCY INDUCTION FURNACE.

FOUNDED on the successful operation of smaller furnaces of the same type, the one-ton high-frequency induction furnace now in operation at the works of Messrs. Thos. Firth and John Brown, Ltd., of Sheffield, indicates the rapid development of this type of melting unit. The advantages of the high-frequency coreless-type induction furnace for the production of high-grade steels are appreciated. This furnace, the order for which was referred to in our issue of December, 1931, is shown in the accompanying illustration. Previous experience with a ¼-ton furnace of this type has shown that steel of a quality equal to that of crucible steel can be produced at about half the cost of the older method. It is confidently expected, however, that the larger unit will show a reduction in running costs, including depreciation, interest on capital, and overhead charges, of about 30% when compared with the ¼-ton furnace.

The complete installation, which is supplied by the Metropolitan-Vickers Co., of Manchester, is the largest of its kind in England. It includes the furnace, high-frequency motor generator, switch-gear, and a bank of static condensers for power-factor correction. The furnace box, containing the water-cooled coil which surrounds the charge, is mounted in a framework of non-magnetic steel, in order to avoid any risk of overheating due to stray magnetic field from the coil.

The motor generator set consists of a single-phase 500-cycles 2,000-volt alternator, with overhung exciter directly coupled to a 1,500-r.p.m. slip-ring induction motor, the rating of the latter being 1,100 b.h.p., and that of the generator 600 kw. at unity power factor. The output is such that the full furnace charge of 1 ton can be melted in approximately one hour. The voltage and power factor are both automatically controlled, the former by a voltage-regulating relay, and the latter by a power-factor regulating relay which, by means of contactors, switches in and out sections of a bank of static condensers. The provision for these automatic features has the great advantage of leaving the furnace operator free to concentrate almost entirely on the metallurgical requirements of the melting process.



One-ton Metrovic high-frequency induction furnace in operation

The switchgear, with the exception of the starting equipment for the motor generator, is of the electrically operated type, and includes a furnace switch cubicle fitted with an electrically operated circuit breaker, protective relays, instrument transformers, etc., a condenser panel, a remote-control board located on the furnace platform, and a small controller for the tilting mechanism. The remote-control panel is fitted with instruments for indicating voltage, current, and power factor, and with push buttons for operating the alternator circuit breaker.

A New Resistance Alloy.

In addition to the nickel-chromium and electric resistance alloys made by Messrs. Hall and Pickles, Ltd. considerable interest is attached to a new metallic resistance alloy which is being marketed by this firm, and known as "Kanthal." This alloy is claimed to be able to withstand temperatures up to 1,325° C. for long periods without the usual disadvantages associated with non-metallic materials. It possesses a much higher specific resistance, and lower specific gravity, than nickel-chromium alloys, and when in the presence of sulphur is attacked only to a very small degree. Produced in strip, wire, castings, and tubes for pyrometer sheaths, it is suitable as elements for all types of furnace work, regardless of design, and has already been used successfully in furnaces for hardening high-speed steel, glass-melting, heat-treating of stainless steel, case-hardening, enamelling, pottery, sintering tungsten carbide, laboratory work, etc.

In comparison with elements of the non-metallic type, the metallic element, it is claimed, gives a much wider range and more economical design of furnace, which will permit of electrical heat-treatment being employed in many trades which hitherto have found it impossible, owing to the form or design of furnace which was necessary when non-metallic elements were used.

Business Notes and News

Awards of the North-East Coast Institution of Engineers and Shipbuilders.

The Council of the North-East Coast Institution of Engineers and Shipbuilders has decided to award the engineering gold medal to Messrs. L. J. Le Mesurier and R. Stansfield for their paper entitled "Combustion in Heavy-oil Engines." Mr. Le Mesurier is chief engineer of the Anglo-Persian Oil Co., Ltd., while Mr. Stansfield is in the research department of the same company.

The shipbuilding gold medal has been awarded to Dr. F. H. Todd, for his paper on "Some Measurements of Ship Vibrations." Dr. Todd is a member of the staff of the National Physical Laboratory, Teddington.

Further awards include the Reed medal, which was founded by the late Mr. Thomas Fenwick Reed, of Cardiff, and is awarded to the candidate who most successfully produces and exhibits evidence of his ability to take a share in the control of industry. It has been decided to award this medal to Mr. W. Spencer Paulin, B.Sc., an assistant manager in the employment of Messrs. Donkin and Co., Ltd.

Special awards have been granted to the following Graduates: Messrs. A. T. S. Sheffer, N. M. Hunter, jr., W. Pratt, R. G. P. Weighton, N. H. Denholm, D. Tagg, and L. H. W. Wright for papers read before the Graduate Section.

Broughton Copper Company.

There has been a heavy decline in the volume of trade, competition has been intensified, and foreign manufactures in particular have been sold in many cases at prices considerably below the cost of production in this country, said Mr. Leonard Sumner at the meeting of the Broughton Copper Co., held recently. The bulk of the Company's trade, he said, is connected with the shipping and shipbuilding industry, the locomotive-building industry, the railways, and the textile industry, and these, its chief customers, are themselves suffering from trade depression. The continued fall in copper prices has also influenced the position since it is necessary to contract for some time ahead to obtain regular shipment of the qualities required. Mr. Sumner was able to point to a satisfactory feature, in that the trade returns available show the Company has, in the aggregate, increased its share of the orders placed in this country. Further, as a result of an independent investigation, efficiency has been increased and many economies achieved.

Extraordinary general meetings of the shareholders, presided over by Sir Robert B. Dixon, K.C.B., who has succeeded Mr. Sumner as chairman of the Company, approved the scheme for reduction and reorganisation of the share capital of the Company.

The Manchester Steam Users' Association Merge Interests.

The Manchester Steam Users' Association has merged its interests with the British Engine, Boiler, and Electrical Insurance Co., Ltd. Founded in 1854 by Sir William Fairburn, Bart., M.Inst.C.E., F.R.S., Sir Thomas Bazley, Bart., Sir Joseph Whitworth, Bart., M.Inst.C.E., F.R.S., Mr. Henry Houldsworth, and other engineers, with the object of reducing the possibility of steam-boiler explosions by subjecting them to scientific inspection by a competent staff, the Association has done effective and useful pioneer work for over 77 years.

As far back as 1859 the late Mr. R. B. Longridge, who was the first inspector of the Association, proposed the issue of an insurance policy as a guarantee of efficient boiler inspection, This suggestion was not accepted by the Committee of the Association, and Mr. Longridge founded the first boiler insurance company, now the Vulcan Boiler and General Insurance Co., Ltd., of Manchester.

The British Engine, Boiler, and Electrical Insurance Co., Ltd., has now taken over the Association's liabilities, its staff and its pension arrangements, and all business will now be conducted through this Company.

The Institution of Heating and Ventilating Engineers.

Examinations for admission as graduate and associate members of the above Institution are held at suitable centres in January, May, and September each year; intending candidates should apply for full particulars to the Secretary, Mr. H. B. Watt, 12, Russell Square, London, W.C. 1.

Electric Furnace Companies enter into a Further Agreement.

G.W.B. Electric Furnaces, Ltd., and Wild-Barfield Elecric Furnaces, Ltd., have entered ir to a working arrangement with Industrie-Elektroofen G.m.b.H., Cologne, whereby the two former firms will manufacture and sell in Great Britain electric furnaces under the Russ patents.

The Russ electric furnaces, which are well known on the Continent, include induction-type melting furnaces, arc furnaces, ferrous and non-ferrous continuous-strip heat-treatment plant, complete with winding gear, etc. Included amongst the Russ designs is a new electric automatic hardening furnace, information on which was published recently in the May issue of this journal. This furnace, which comprises a salt-bath, heated electrically, maintains and accurately records hardening temperature, charging time, duration of heat, and discharging time, and, in addition, it eliminates rejects.

This agreement, together with that made with the Hevi Duty Electric Furnace Co., of Milwaukee some time ago, places these British companies in a position to manufacture and supply practically every type of electric furnace required for industrial purposes.

New Heat-resisting Plant.

A new development in the painting of engine parts subjected to heat is made possible by the discovery of a new paint which is a rust-preventive, and is actually improved by intermittent heating and cooling action. This paint, which is manufactured by Nobel Chemical Finishes, Ltd., and known as Kemick heat-resisting paint, it is claimed, will not come off or burn off hot metal at red or even white heat, and its efficiency in protection against rust is in no way lessened at these extreme temperatures.

Kemick is a paint with a liquid and volatile content, which serves to spread the material evenly on the surface and hold the pigment in place before heating. Heat which decomposes ordinary paint and renders it useless, changes this new paint giving it a finish which will adhere to the surface and prevent oxidation for an indefinite period. It retains its colour at all times. When applied it is black, but when heated it bubbles slightly and liberates a fine white powder which, mixed with the black pigment, gives a permanent dark-grey colour. No special skill in application is necessary, and the surface to which it is applied need not be as clean and polished as would be required for an ordinary enamel, although old paint, oil, grease, and loose rust should be removed.

Faster Iron Smelting.

In order to effect economies in the production of pig iron for the foundries, the Staveley Coal and Iron Co., Derbyshire, has built and put into commission two new cupolas of the balanced-blast type, developed by the British Cast Iron Research Association. In comparison with the older internal-diameter cupola, the operation of smelting is quicker and a a saving in labour costs is effected.

Alloys of Iron Research.

Organised by the Engineering Foundation, with the assistance of an Advisory Committee appointed by the American Institute of Mining and Metallurgical Engineers and the co-operation of many institutes and technical societies, the alloys of iron research has made substantial progress during the past year. The critical survey of research on iron and its alloys, published since 1890, is more than 50% complete, and the publication programme is well advanced. The completed manuscript for the first monograph, that on iron-molybdenum, written by J. L. Gregg, of Battelle Memorial Institute, is now in press and should be available in the early autumn.

The second monograph, which deals with iron-silicon, is expected to go to press in the late autumn for publication in the spring of next year. The alloy systems, iron-tungsten and iron-copper, will be considered in the third and fourth monographs. Altogether, work has been done, or is planned, for six additional publications of this character.

To accomplish the most thorough survey in the shortest time the review to date has been confined to the most important metallurgical journals; more than half of these—in English, German, French, Swedish, and Italian—have been abstracted, and all information of value for monographs and manuals have been abstracted and filed. The comprehensiveness of this survey will be appreciated when it is understood that over 3,540 technical and scientific papers have been reviewed and over 9,420 abstracts prepared.

Business Notes and News—continued.

Crewe Steel Works.

The L.M.S. Railway have postponed the closing down of their steel-smelting works at Crewe by placing an order for making steel rails. It is stated that over 200 miles of rails, involving 5,000 tons of steel, are included in the order. The order will enable the steel works to continue in operation until the end of September, when they will be closed down. The official statement of the Company with regard to closing the works reads :—" The London, Midland and Scottish Railway Co. have reluctantly come to the conclusion, after very full consideration, that they can no longer continue economically to manufacture steel at their steel works. The Company is faced with the alternatives of incurring heavy capital and renewal expenditure for modernisation, or ceasing to manufacture, and obtaining their supplies from the steel producers.

" In view of the capacity of the existing steel plants in the country, and the national importance of economic production of steel in Great Britain at the present time, the expenditure necessary to modernise the forge and rolling mills cannot be justified."

The Crewe works—the only ones of their kind on the L.M.S. system—were entirely occupied in producing steel rails, and have not been supplying all the needs of the Company, who took a proportion of them from producers elsewhere in Great Britain. Other railway companies regularly give the whole of their orders to British manufacturers, the L.N.E.R. placing theirs chiefly with concerns at Frodingham (Lincs.), Sheffield, Middlesbrough, Darlington, and Glasgow. Altogether, about 210,000 tons of new steel rails are wanted every year by British railways, who spend approximately £16,000,000 per annum on maintenance and renewal of railway tracks. In 1931 a total of 1,359 miles of track were renewed.

Launching at Barrow.

Lady Fuller, the wife of Admiral Sir Cyril T. M. Fuller, K.C.B., C.M.G., D.S.O. (late Second Sea Lord), has kindly consented to launch H.M. Submarine, *Porpoise*, at present under construction at the naval construction works of Vickers-Armstrongs, Ltd., Barrow-in-Furness. The launch will take place on August 30. The *Queen of Bermuda*, now being built by Vickers-Armstrongs, Ltd., for the New York-Bermuda service of Furness, Withy and Co., Ltd., will be launched on September 1, 1932, by Lady Cubitt, the wife of His Excellency Lieut.-General Sir Thomas Astley Cubitt, K.C.B., Governor of Bermuda.

New Metallurgical Works at Bashkiria.

The Technical Council of the Commissariat for Heavy Industries of the U.S.S.R. has approved the main plan for the new Zigazino-Komarsk metallurgical works in Bashkiria. The projected works are to have six blast furnaces of the Magnitogorsk type, capable of an annual production of 1·5 million tons of pig iron, two martensite shops, capable of producing 1·8 million tons of steel castings, and a rolling shop, capable of an output of 800,000 tons of high-quality steel a year. The works are also to turn out 500,000 tons of pipes a year.

The works are at first to work on coal from Cheliabinsk and Karaganda, but the recent discovery of deposits of high-quality slate, some 15 km. from the site of the works, and rich deposits of oil about 80 km. from site, will, in time, make it possible to dispense with the transportation of coal from Cheliabinsk and Karaganda. The details of the production are to be worked out within the next few weeks, when the draft for the building and technical plant will be made and the date fixed for the commencement of building operations.

N.-E. Coast Engineers.

The session's work of the North-east Coast Institution of Engineers and Shipbuilders is to open on October 21, when the annual general meeting will be held, and Mr. R. J. Walker, C.B.E., will deliver a presidential address. The list of papers will be announced in a few weeks' time. On November 11, Mr. E. Leslie Champness, M.Sc. (Naval architect to Palmer's Shipbuilding and Iron Co., Ltd.) will deliver a paper entitled " Fire at Sea." The prevention of such disasters as occurred recently to the *Georges Philippar* is continuing to occupy the thoughts of shipbuilders and naval architects throughout the world, and it is expected that Mr. Champness's paper will attract universal attention.

Magnetic Concentration at Mineville, New York.

The ore treated is magnetite in a gangue composed essentially of gneiss and apatite. It is mined by open-stope methods, three large ore bodies furnishing most of the tonnage. In 1930 the average tenor of the ores from these three deposits, in percentage of iron, was as follows : Old bed, 52·57 ; Harmony, 40·26 ; new bed, 29·79.

Magnetic concentration was first applied at Mineville in 1853, but was unsuccessful. Wet-milling by means of jigs was later introduced in the district, but likewise met with failure. Dry magnetic separation with drum-type machines was instituted in 1902, and has continued in use, with modifications in flow-sheets and equipment, ever since. Five mills have been built, but three were destroyed by fire ; construction of a sixth is contemplated at present.

In a general way the process consists of :—

(1.) Breaking to 4-in. maximum size.

(2.) Intermediate crushing in gyratories to 2 in.

(3.) Screening, the fines going to drum separators, where shipping concentrates and middlings to the dryer are made ; the oversizes are screened to three sizes—minus 1¼ in., which goes to the dryer ; plus 1¼ minus 2 in., which goes to pulley-type separators ; and plus 2 in., which is returned to intermediate crushing. Trommels and vibrating screens are used at various points in the flow-sheet to distribute the feed, and to effect plus and minus 10-mesh segregation of the feed to the separators which make final shipping products.

(4.) Drying of minus 1¼-in. material prior to final separation of shipping concentrates and tailings.

(5.) Magnetic separation, involving three types of machines —pulley, drum, and belt. The pulley type is used primarily as a cobbing machine to make middling and clean tailing ; the drum type is employed to produce concentrate and middling ; and the belt type is used on the finer sizes for making concentrate, middling, and tailing.

(6.) Fine crushing to about 10-mesh by means of rolls, operated in open circuit on middlings from various points in the flow-sheet. This is the final stage in size reduction, and no fine grinding in the commonly accepted sense of the term is employed.

(7.) Conveying of concentrate to shipping bins on conveyer belts.

(8.) Disposal of dry tailings by means of conveyers and surge bins. Some tailings are sold for road construction, the balance being stacked in large piles or dumps.

Samples for mill control are taken at various points, quick determination of magnetic iron being made in an ingenious apparatus consisting essentially of a glass tube held between the poles of a magnet. The sample is agitated, with water flowing through the tube ; magnetite is retained in the tube by the magnet while the gangue is washed out.

Mining Research Laboratory's Work.

The annual report of the Executive Board of Mining Research on the work of the Mining Research Laboratory at the Birmingham University states that hydrogenation investigations in the laboratory have been discontinued because the minimum cost of large-scale production cannot be brought sufficiently low to compete with the present exceedingly low price of imported petrol and oil fuel.

The report states several meetings have taken place between representatives of the Fuel Research Division and of the Mining Research Laboratory during the year which have been helpful in deciding the most profitable lines for experimental work on hydrogenation and other means of increasing the utilisation of coal. Since the issue of the report for last year experimental work has been concentrated on lines connected with previous work, which it had been considered advisable to cover by patent application.

Investigations have shown that by preheating of certain coals in the absence of added hydrogen, or of oxidising gases to a temperature of between 300° and 470°, and subsequently hydrogenating in the usual manner, a larger conversion of the coal into oil is possible than by direct hydrogenation of the untreated coal. Experiments have shown that steam has an appreciable oxidising action on coal, in the case of certain coals even at a temperature as low as 250° C., and, further, that the presence of water in coal exerts an inimical influence upon the hydrogenation process. As a result of a large number of experiments, it has been shown that the optimum conditions in regard to the time, temperature, and pressure under which the preliminary heat-treatment is carried out vary with the nature of the coal.

Some Contracts.

Simon-Carves, Ltd., of Cheadle Heath, near Manchester, has received an order from the Manvers Main Collieries, Wath-on-Dearne, South Yorkshire, for coke ovens, by-product plant, and coal and coke handling equipment of the approximate value of £150,000.

Oil Installations (1928), Ltd., Hammond Works, Victoria Road, N.W. 10, have received an order from the Egyptian General Omnibus Co., of Cairo, for four complete model "M" low-pressure petrol metering systems.

The Vulcan Foundry, Ltd., Newton-le-Willows, Lancs., has secured the annual contract for the supply of superheated boilers during 1932-33, placed by the Controller of Stores, North-Western Railway, Lahore. The contract is for six boilers, H.P./S (4-6-0) class, valued at Rs. 1,08,135 c.i.f. Karachi.

Standard Telephones and Cables, Ltd., of Aldwych, London, has been awarded a contract by the New Zealand Government Railway Department, Wellington, for a transmission line, comprising about 26 miles of 20- and 40-pair multiple-twin, dry-core, lead-covered and armoured telephone cable, together with loading coils and other associated equipment. This transmission line is required in connection with the electrification of the Wellington-Packakariki section of the New Zealand Government Railways.

G. D. Peters and Co., Ltd., have received an order from the Iraq Petroleum Co., Ltd., for 14 Wilson "S" type portable petrol-driven electric-arc welding plants for use on the construction of the Iraq pipe line.

The Patent Shaft and Axletree Co., Ltd., of Wednesbury, Staffs., have been awarded the contract, by the Union of South Africa Railways and Harbours Administration, for the supply of the steelwork for four 150-ft. skew-through spans and abutments required for the new Umlaff River bridge, Natal.

H. Tollemache and Co., Ltd., of Canada House, Norfolk Street, London, W.C. 2, have received a contract from British Insulated Cables, Ltd., for pulverised-coal plant in connection with the new copper refinery now in course of construction at Prescot, Lancs.

John Fowler and Co. (Leeds), Ltd., have received orders for two oil-engined locomotives for a sugar estate in Natal. These engines are of 30 h.p., of the 0-4-0 type, and are intended for working on a 2-ft. gauge track. A similar locomotive is now under construction for Imperial Chemical Industries (Lime), Ltd., of Buxton. For Roads Construction, Ltd., of Bristol, a 100-h.p. oil-engined locomotive for working on main-line gauge track is in hand.

John Baker and Bessemer, Ltd., of Rotherham, have been awarded a contract for wheels and axles for new motor coaches for the Copenhagen suburban railway electrification, the electric equipment for which is being supplied by the English Electric Co., Ltd.

The Blythswood Shipbuilding Co., Ltd., Scotstoun, has secured an order for an oil-carrying steamer for London owners. The machinery, consisting of single-screw triple-expansion engines, with oil-fired boilers, will be supplied by David Rowan and Co., Ltd., Glasgow.

John I. Thornycroft and Co., Ltd., have received an order from the Cleveland Bridge and Engineering Co., Ltd., for a motor-launch for service on the Zambesi River, in connection with the work now in progress for the construction of the Lower Zambesi bridge and connecting railways.

Braithwaite and Co. (Engineers), Ltd., of West Bromwich and Westminster, has secured a contract for the supply and erection of about 260 tons of steel-structural work for the new car-cleaning sheds at West Worthing, in connection with the Southern Railway Co's electrification scheme. This firm has also secured an order for 220 tons of steelwork and corrugated roofing, etc., for the locomotive repair shops of the Colombian National Railway, at Cali.

Albion Motors, Ltd., of Scotstoun, has been awarded a contract for the supply of 14 flat 1½-ton and 6 flat 2-ton platform vehicles from the London and North Eastern Railway Co., Ltd.

Sir W. G. Armstrong, Whitworth and Co. (Engineers), Ltd., are supplying four railcars for the Gaekwar's Baroda State Railways, India, one of which has recently been undergoing trials on the 2-ft. 6-in. gauge Manifold Valley branch of the London, Midland and Scottish Railway in North Staffordshire.

R. and W. Hawthorne, Leslie, and Co., Ltd., of Hebburn-on-Tyne, have secured the contract for the repair of the liner *Euripides*, owned by Shaw, Savill, and Albion Co., Ltd., and its conversion from coal burning to oil burning. This vessel was built by Harland and Wolff, Ltd., at Belfast, in 1914, and is of 14,947 tons gross.

Catalogues and Other Publications.

We have received a brochure from the British Oxygen Co., Ltd., which gives full particulars of this Company's dissolved acetylene flarelights, more especially those known as "Alda-lights" and "Da-lights." These flarelights consist of a cylinder of dissolved acetylene, to which is attached a burner fitment and reflector. They are wind and rain proof, and will burn without attention until the cylinder is exhausted. Copies of this brochure are available on application to the Company's offices, Angel Road, Edmonton, London, N. 18.

A new publication has been received from the Butler Machine Tool Co., Ltd., which deals with a range of this Company's machines, double standard, open side, and rail planers, with belt drive or with patent forced-feed reversing equipment. Valuable constructional information is given which indicates the careful study to which each unit and component part is submitted, both as regards design and material employed, in order to produce a reliable machine. Copies may be obtained from Victoria Iron Works, Halifax, England.

The June issue of Bradley's mazagine contains much that is of interest. It contains an informative article on "The Evaluation of the Inherent Mechanical Strength Properties of Cold-blast Irons," while another article deals with a practical method of studying the running quality of a metal cast in foundry moulds. A service page, allocated to problems, gives some details of an important investigation relating to malleable casting manufacture. It is published by Bradley and Foster, Ltd., Darlaston Blast Furnaces, Darlaston, Staffs.

An attractive constructional steel is referred to in a leaflet from Samuel Osborn and Co., Ltd. This steel is made in three qualities, the first having a strength range of 32—38 tons, the second 40—45 tons, the third as high as 50 tons per square inch. These steels can be supplied in bars of any section and as forgings. Heat-treatment information in regard to each quality, together with mechanical properties, is also given. The leaflet is marked Section A 17, and may be obtained from Clyde Steel Works, Sheffield.

Aluminium Broadcast, No. 35, contains short notes of the activities of Committees of the A.S.T.M. of interest to the aluminium industry; an abstract of Meigh's article in a recent issue of the *Revue de Metallurgie*, dealing with different applications of aluminium bronze; a fairly full translation of an article by R. Schaumann, in the V.A.Y.Z., dealing with the use of light-alloy castings in the electrical industry; together with other useful abstracts and information. It is issued by the Intelligence Department of the British Aluminium Co., Ltd., Adelaide House, London, E.C. 4.

The present position of the light aluminium alloys in engineering practice is reviewed in the July *Nickel Bulletin*. Among the most important are alloys containing nickel and other elements, which afford the designer a means of cutting down the weight to facilitate their application in the transport industries, and in some cases to machinery with the object of increasing output. This issue also includes information on some recent issues of nickel coinage which, together with the customary abstracts and references, make it a useful one. It is published by The Bureau of Information on Nickel and the Mond Nickel Co., Ltd., Millbank, London, S.W. 1.

MARKET PRICES

ALUMINIUM.

98/99% Purity	£95	0	0

ANTIMONY.

English	£35 0 0 to £42	10	0
Chinese	23	10	0
Crude	16	0	0

BRASS.

Solid Drawn Tubes	lb.	8¾d.
Brazed Tubes	lb.	10¾d.
Rods Drawn	,,	7½d.
Wire	,,	7½d.
*Extruded Brass Bars	,,	3⅞d.

COPPER.

Standard Cash	£30	10	0
Electrolytic	35	10	0
Best Selected	33	5	6
Tough	32	15	0
Sheets	59	0	0
Wire Bars	35	0	0
Ingot Bars	35	0	0
Solid Drawn Tubes	lb.	9½d.	
Brazed Tubes	,,	9½d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	2	0
‡Ferro Tungsten	,,	0	1	9
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2-4% Carbon, scale 12/- per unit	ton	35	15	0
NOMINAL 4-6% Carbon, scale 8/- per unit	,,	27	5	0
NOMINAL 6-8% Carbon, scale 8/- per unit	,,	24	15	0
NOMINAL 8-10% Carbon, scale 8/- per unit	,,	23	15	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/6 per unit	,,	37	17	6
Guar. max. 1% Carbon, scale 14/ per unit	,,	42	0	0
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	46	0	0
‡Manganese Metal 96-98% Mn.	lb.	0	1	4
‡Metallic Chromium	,,	0	2	8
§Ferro-Vanadium 25-50%	,,	0	12	8
§Spiegel, 18-20%	ton	6	17	6
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	6	5	0
20/30% basis 25%, scale 3/6 per unit	,,	8	17	0
45/50% basis 45%, scale 5/- per unit	,,	13	10	0
70/80% basis 75%, scale 7/- per unit	,,	18	17	6
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	12	5	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20-25%	ton	21	10	0

FUELS.

Foundry Coke—						
S. Wales	£1	2	6 to	1	16	6
Sheffield Export	0	13	6 to	0	15	6
Durham				1	4	0
Furnace Coke—						
Sheffield	0	13	6 to	0	15	6
S. Wales	0	17	0 to	0	18	0
Durham	0	13	0 to	0	13	6

GUN METAL.

*Admiralty Gunmetal Ingots (88:10:2)	£44	0	0
*Commercial Ingots	35	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0 9
*Cored Bars	,,	0	0 11

LEAD.

Soft Foreign	£10	13	9
English	13	15	0

MANUFACTURED IRON.

Scotland—				
Crown Bars, Best	£10	5	0	
N.E. Coast—				
Rivets	11	0	0	
Best Bars	10	10	0	
Common Bars	10	0	0	
Lancashire—				
Crown Bars	9	15	0	
Hoops	£10 10 0	to	12	0 0
Midlands—				
Crown Bars	£9 15 0	to	10	0 0
Marked Bars	12	0	0	
Unmarked Bars	—			
Nut and Bolt Bars	£8 7 6	to	8	12 6
Gas Strip	10	12	6	
S. Yorks.—				
Best Bars	10	10	0	
Hoops. Hoops	£10 10 0	to	12	0 0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	9d.
*Cored Bars	,,	11d.
†Strip	,,	10¼d.
†Sheet to 10 W.G.	,,	10¾d.
†Wire	,,	11¼d.
†Rods	,,	11d.
†Tubes	,,	1/3½
†Castings	,,	1/1½

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	8	6
Foundry No. 1	3	12	0
,, No. 3	3	9	6
N.E. Coast—			
Hematite No. 1	3	4	0
Foundry No. 1	3	1	0
,, No. 3	2	18	6
,, No. 4	2	17	6
Cleveland—			
Foundry No. 3	2	18	6
,, No. 4	2	17	6
Silicon Iron	3	1	0
Forge No. 4	2	17	0
N.W. Coast—			
Hematite	3	14	6
Midlands—			
N. Staffs Forge No. 4	3	1	0
,, Foundry No. 3	3	6	0
Northants—			
Forge No. 4	2	17	6
Foundry No. 3	3	2	6
Derbyshire Forge	3	1	0
,, Foundry No. 3	3	6	0
West Coast Hematite	3	6	0
East ,, ,,	3	3	6

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	94 KRONOR.					
Billets	£12	13	6 to	£16	0	0
Wire Rods	£14	12	0 ,,	£17	12	6
Rolled Bars (dead soft)	£10	4	0 ,,	£11	11	0
Rolled Charcoal Iron Bars	—			£16	0	0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£23	0	0
,, Braziery	19	0	0
,, Wire		—	
Brass	15	0	0
Gun Metal	19	0	0
Zinc	6	0	0
Aluminium Cuttings	72	0	0
Lead	7	0	0
Heavy Steel—			
S. Wales	1	17	6
Scotland	1	15	0
Cleveland	1	15	0
Cast Iron—			
Midlands	1	15	0
S. Wales	2	0	0
Cleveland	1	16	0
Steel Turnings—			
Cleveland	1	10	0
Midlands	0	19	6
Cast Iron Borings—			
Cleveland	1	2	6
Scotland	1	10	0

SPELTER.

G.O.B. Official		—	
Hard	£10	5	0
English	13	15	0
India	12	0	0
Re-melted	12	0	0

STEEL.

Ship, Bridge, and Tank Plates—			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	9	0	0
,, ,, (Marine) ,,		—	
,, ,, (Land), N.E. Coast	10	0	0
,, ,, (Marine) ,,	10	10	0
Angles, Scotland	8	7	6
,, North-East Coast	8	7	6
,, Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails	£8 10 0 to	8	15 0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic	£8 2 6 and	8	12 6
Medium Basic	£6 12 6 and	7	2 6
Soft Basic	6	0	0
Hoops	£9 10 0 to	9	15 0
Manchester—			
Hoops	£9 0 0 to	10	0 0
Scotland, Sheets 24 B.G.	10	5	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/-
Finished Bars 18% Tungsten	lb.	2/9
Extras		
Round and Squares, ¼ in. to ½ in.	,,	3d.
Under ¼ in. to ⅛ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅛ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£127	10	0
English	143	15	0
Australian	145	0	0
Eastern	148	0	0
Tin Plates I.C. 20 × 14 box	14/9	15/3	
Block Tin (Cash)	120	12	6

ZINC.

English Sheets	£22	10	0
Rods	26	0	0
Battery Plates		—	

* McKechnie Brothers, Ltd., quoted Aug. 8. † C. Clifford & Son, Ltd., quoted Aug. 8. ‡ Murex Limited, quoted Aug. 8

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

§ Prices quoted Aug. 8, ex warehouse.